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Determining Some Quality Properties of Oat Genotypes Collected from the Middle and West Black Sea Region

Zeki Mut[1], Hasan Akay[2,*], Özge Doğanay Erbaş Köse[1], and İsmail SEZER[3]

[1]Bilecik Şeyh Edebali University, Faculty of Agriculture and Natural Sciences, Department of Field Crops, Bilecik, Turkey
[2]Ondokuz Mayıs University, Bafra Vocational School, Department of Plant and Animal Production, Samsun, Turkey
[3]Ondokuz Mayıs University, Faculty of Agriculture, Field Crops Department, Samsun, Turkey

Author for correspondence: Email: hasan.akay@omu.edu.tr; akay.hsn@gmail.com

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Healthy foodstuffs, including functional foods, are the key component of a healthy and prosperous life. Oat grains are rich in protein, soluble dietary fiber, β-glucan, starch, oil, some vitamins and minerals, and thus accepted as a healthy foodstuff. This study was conducted to determine physical and chemical quality traits of many different oat landraces/cultivars. In this study, 251 local oat genotypes, collected from 10 provinces of Western and Middle Black Sea Regions of Turkey and four standard oat cultivars were grown over the experimental fields of the Agricultural Application and Research Center at Samsun Ondokuz Mayıs University for two years in an augmented experimental design. As a result of the research, the screenings percentage >2 mm ranged from 69.81 to 95.80%, thousand grain weight from 18.55 to 38.41 g, protein content from 8.82 to 14.81%, starch content from 33.15 to 51.32, β-glucan content from 2.44 to 3.93%, acid detergent fibre value from 18.1 to 18.95%, and neutral detergent fibre value from 27.83 to 36.66%. Also, the local oat genotypes exhibited significant variations in fat content (3.70–7.91%), linoleic acid content (31.89–38.37%), oleic acid content (35.03–44.77%), palmitic acid content (18.26–22.87%), and stearic acid content (1.50–1.96%). According to the biplot, it was determined that the investigated quality traits differed according to the genotypes collected from the provinces. Also, these results can be used for selection of precious pure lines and improvement of new varieties for oat breeding programs.

Keywords: oat, local genotype, quality, biplot

Abbreviations: AACC—American Association of Cereal Chemists, ADF—acid detergent fiber, DAP—diammonium phosphate, NDF—neutral detergent fiber, PC—principal components, TGW—thousand-grain weight, SP—screenings percentage

INTRODUCTION

Oat (*Avena sativa* L.) is a minor cereal used primarily for animal feed, human food, and industry purposes (Buerstmayr et al. 2007). It is well-adapted to different soil types and on acid soils and can perform better than other small-grain cereals. Oat is largely planted in cool, moist climates and can be sensitive to hot, dry weather between head emergence and maturity (Hoffmann 1995).

The world's annual total oat production is around 23 million tons and the annual oat production of Turkey is about 260 thousand tons (FAO 2020). In the past, oat played an important role in the development of world agriculture. However, since greater investments were made in wheat and barley in the 21st century, developments in yield potential and the other agronomic traits of oat made slower progress and oat genetics were less comprehended. Toward the end of the 20th century, oat studies revealed that cultivated oat populations had a high genetic diversity (Winkler et al. 2016). Such diversity constitutes a highly valuable source for the future of oat farming since it allows the cultivation of diverse ecologies and adaptation of oat genotypes for desired quality traits (Winkler et al. 2016).

Oat grain has a number of nutritional benefits compared to other cereals. It is rich in protein, dietary fiber, β-glucan, starch, oil, and vitamins and minerals; thus, it is accepted as a healthy foodstuff (Sterna et al. 2016). Functional foods constitute principal components of a prosperous and healthy lifestyle. Oat grains are used in human nutrition and animal feeding and oat herbage is used in animal feeding in various countries of the world

(Özcan et al. 2006). Oat and its components are also known to have different pharmacological activities like antioxidant, anti-inflammatory, immunomodulatory, anti-diabetic, and anti-cholesterolaemic (Biel et al. 2009).

The grain weight, screenings percentage, test weight, starch, protein, oil, and β-glucan contents are the basic physical and chemical properties that determine the grain quality of oats (Doehlert et al. 2001; Peterson et al. 2005). Oat grain contains an average of 9–17% protein, 5 –12% fat, 27 –50% starch, 2.7–7.5% β-glucan and has a rich content in terms of vitamins, minerals, and fatty acids (Forsberg and Reeves 1992). In addition to human nutrition, oat proteins with high biological value due to their balanced essential amino acid content increase rapidly in the use of phytotherapy in the pharmaceutical industry and alternative medicine, especially with the emergence of their medicinal benefits in recent years (Forsberg and Reeves 1992).

Thousand grain weight and screenings percentage are both used to predict the milling yield (Doehlert et al. 2001). Usually, millers demand large grain size because they make larger flakes. Millers separate large and small grains by setting standard grading procedures and thus they desire uniformity in grain size distribution across genotypes (Valentine et al. 2011). Therefore, the selection of those genotypes producing uniformly large grains in the early stage of the breeding cycle is important for the milling industry. Fats are food components with a great role in the organism. Either high or low fat contents are desired in oat grains depending on the intended use. High fat content is desired if the oat grains are to be used in animal feeding since high fat contents supply high calories. On the other hand, high fat contents are not desired if the grains are to be used in foodstuffs since high fat contents induce staling and result in tasteless production (Doehlert et al. 2001). Oat fat is mostly composed of oleic (C18:1) and linoleic (C18:2) unsaturated fatty acids and has a balanced fatty acid composition (Givens et al. 2004). Acid detergent fiber (ADF) expresses cellulose, lignin, and insoluble protein content of cell membrane and neutral detergent fiber (NDF) expresses cellulose, hemi-cellulose, lignin, cutine, and insoluble protein content of the cell membrane. Low ADF levels increase feed digestibility and energy values (Mut et al. 2018) and low NDF levels increase animal feed intake (Van Soest et al. 1991).

Plant genetic resources are very important for plant breeding programs. Turkey is a country with such resources and plant diversity because it is located at the junction of Mediterranean and Near-East gene centers. Important gene sources should be collected, identified, and preserved accordingly for the sustainability of agriculture, to meet the needs of breeding programs, and to prevent the extinction of genetic diversity. White oat (*Avena sativa* L.) and red oat (*Avena byzantina* Koch.) are known to be originated in Anatoli and are largely cultivated in different regions of Turkey (Şehirali et al. 2005). Oat is dominantly a self-pollination species, but 1–2% foreign-pollination may also be seen in oat species. Gene transitions are encountered between oat species and varieties with a large genetic base through pollination (Vilaro et al. 2004). In the present study, 251 oat landraces collected from the Western and Middle Black Sea regions of Turkey were grown under Samsun conditions for two years and some physical and chemical quality traits were determined and province-based genetic variations were identified.

MATERIALS AND METHODS

Plant Material and Crop Management

As plant material, four check cultivars and 251 oat landraces collected from 10 provinces with different altitudes (15 –1424 m) in the middle and western Black Sea regions of Turkey were used. The information about the landraces was given in the supplementary file (Table S1).

These collected landraces with four check cultivars were grown over the experimental fields of Agricultural Research and Implementation Center of Ondokuz Mayıs University Agricultural Faculty for two years (2008–2009 and 2009–2010 growing seasons) in an augmented experimental design. In both years, the experimental design consisted of 12 blocks containing 25 genotypes each with 21 test genotypes and four check cultivars (Faikbey, Seydişehir, Yeşilköy-330, and Yeşilköy-1779). Each plot consisted of four rows of 6 m length with 20 cm between the rows. The seeding density was 450 seeds m^2. Sowing was performed manually in November of both growing seasons. Before sowing, 130 kg ha^{-1} diammonium phosphate (DAP) and 80 kg ha^{-1} ammonium nitrate (33% N) fertilizers were applied and 130 kg ha^{-1} ammonium nitrate (33% N) was applied at tillering stage of the plants. For weed control, herbicide (Tribenuran-methyl (DF) 75% for broad-leaf species) treatments were performed at tillering period. Harvest was manually performed in June as the plants ripened and samples were threshed with a plot thresher.

Samsun province, where the present experiments were conducted, is located in the Middle Black Sea Region between 41° 17' north parallels and 36° 20' east meridians and an average altitude of 43 m. Long-term average precipitation and temperatures of the research

site and values of experimental years are presented in Figure 1 and soil characteristics of the experimental fields are provided in Table 1.

Analytical Measurements

Screenings percentage (>2 mm), thousand-grain weight, protein content, starch content, β-glucan content, acid detergent fiber (ADF), neutral detergent fiber (NDF) contents, fat content, fatty acid content (palmitic (16: 0), stearic (18: 0), oleic (18: 1), and linolenic (18: 2) acids) of the oat genotypes were determined.

Physical Quality

Thousand-grain weight (TGW) was determined by weighing 1000 seeds counted with a seed-counting device (Chopin Technologies-Numigral). For screenings percentage (SP), weight percentage of grains larger than 2 mm was measured by sieving 100 g of grains on a Sortimat laboratory machine.

Chemical Quality

Oat grains separated for chemical analyses were freed of any foreign materials and ground in a hammer mill to pass through a 0.5 mm sieve. Ground samples were preserved in a fridge at +4°C until the analyses. The measurement for the quality traits was done twice taken from the samples of each genotype and taken from the mean values. Protein (%, N x 6.25) contents were determined according to AACC International Methods 46 -30.01, respectively (American Association of Cereal Chemists 2000). β-glucan and starch contents of samples were determined with the aid of enzymatic test kits (Megazyme International, Bray, Ireland) according to AACC Approved Methods 32-23.01 and 76-13.01, respectively (American Association of Cereal Chemists 2000). The ADF and NDF content (Van Soest et al. 1991) were determined by using an ANKOM 220 Fiber Analyzer. Fat content was determined using the Soxhlet method (Welch 1977). The fatty acid profile was determined with a direct method of extraction and

Table 1: Some physical and chemical properties of trial area soils.

Soil characters	2008-2009	2009-2010
Soil texture	Clay	Clay
Organic matter (%)	2.87	3.13
Phosphorus content (mg kg^{-1})	26.61	25.4
Potassium content (mg kg^{-1})	30.59	35.12
Amount of lime	Non-limy	limy
Salinity	Non-salty	Non-salty
pH	7.08	7.6

* The analyses were carried out in Ondokuz Mayıs University Faculty of Agriculture, Department of Soil Laboratories.

methylation according to O'Fallon et al. (2007) to obtain fatty acid methyl esters (FAME). The methyl esters of the fatty acids (0.5 mL) were analyzed in a Shimadzu GC 2010 equipped with a flame ionizing detector, a fused silica capillary column (MN FFAP, 60 m x/0.32 mm i.d.; film thickness, 0.25 μm). It was operated under the following conditions: oven temperature programme, 120°C for 1 min raised to 240°C at a rate of 6°C per min and then kept at 240°C for 15 min; injector and detector temperatures, 250 and 260°C, respectively; carrier gas, helium at a flow rate of 40 mL/min; and split ratio, 1/20 mL per min. The fatty acid composition [palmitic (16:0), stearic (18:0), oleic (18:1), and linolenic (18:2) acids] was determined by computing integrator. In this study, palmitic, stearic, oleic, and linolenic acids accounted approximately for 98% of total fatty acids. Results were expressed as the mean on a dry weight basis. Statistical Analysis The data collected in the two years were analyzed using a modified augmented design (Lin and Poushinsky 1985). The mean values of the 255 genotypes for investigated traits were subjected to genotype-by-trait, principal components (PC) factor analysis, and biplot analysis of PC1 and PC2 between mean values of the investigated traits were calculated. Cluster analysis was conducted to show similarities among the genotypes (JMP 2013).

RESULTS AND DISCUSSION

In the present study conducted with 251 oat landraces collected from Western and Middle Black Sea Region and

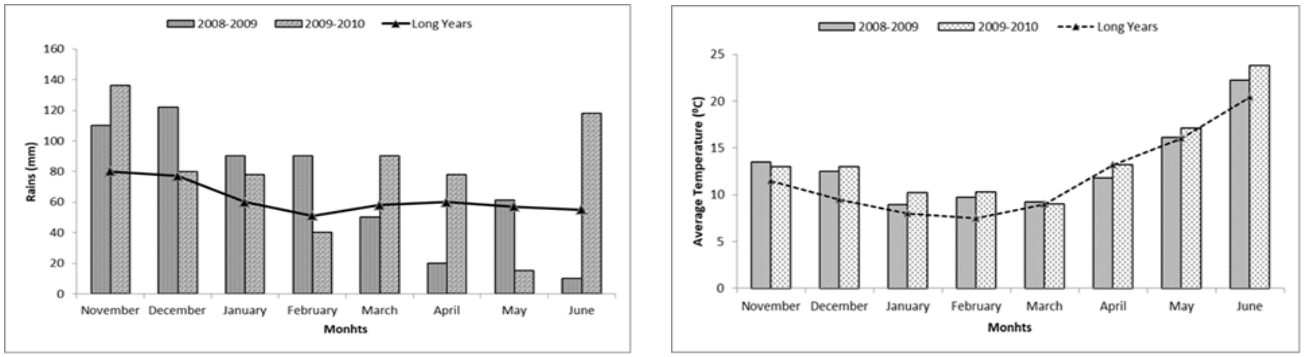

Fig. 1. Relationship between phosphorus-sulphur ratio and yield of tobacco.

four standard cultivars, highly significant differences were observed in investigated traits of the years ($p < 0.01$). Significant differences were observed in screenings percentage, thousand-grain weight, protein content, fat content, ADF, and palmitic acid contents of the genotypes (Table 2). Genotype histogram graphs are presented in Figure 2. Differences in total precipitation, average temperature, and monthly distribution of precipitations in experimental years resulted in significant differences in investigated parameters of the years. The descriptive data (mean, standard deviation [SD], standard error of the mean [SEM], minimum, maximum) of the 12 quality traits are also shown.

Screenings Percentage

Screenings percentage (>2 mm) varied between 69.81–95.80% with an average value of 94.27% in cultivars and 86.78% in landraces. According to Figure 2, about 50% of the genotypes (129 genotypes) had a screenings percentage of 85–90%. Screenings percentage of the genotypes G21, G23, G35, G53, G60, G80, G135, and G148 stayed out of the normal distribution. Screenings percentage was higher in the first year than in the second year (Table 2). The G34, G93, G94, G102, G120, G138, G170, G182, G231, and G240 landraces were higher in screenings percentage (Table 3). Buerstmayr et al. (2007) conducted a study with 120 husked and naked oat genotypes and reported screenings percentage between 46.9–98.7% and indicated significant variations among the genotypes and high heredity. Brunava et al. (2014) also conducted a study with husked and naked oats and reported screenings percentage (>2.2 mm) of husked oat between 87.2–90.6% in the first year and between 93.5–96.0% in the second year. Buerstmayr et al. (2007) indicated screenings percentage as an important quality criterion for oat grains. Oat grains may have different sizes because of prolonged tillering durations, increasing panicle lengths, number of spikelet in panicle, and number of grains in a spikelet. Depending on their use, large grains are generally preferred in oat farming. Oat grains to be used in oatmeal should be dehulled; thus, large grains are preferred to have greater kernel ratios.

Thousand-Grain Weight

Thousand-grain weights of oat genotypes varied between 18.55–38.41 g with an average value of 27.93 g in landraces and 34.52 g in cultivars (Fig. 2). Results also show that the thousand-grain weight of 230 genotypes was greater than 25 g. The lowest thousand-grain weight was obtained from genotype G66 and the greatest values were obtained from the G70, G73, G74, G78, G81, G93, G96, G144, G253, (Yeşilköy-330) and G254 (Yeşilköy-1779) numbered genotypes (Table 3). These genotypes stayed out of the normal distribution (Fig. 2). A significant variation was also observed in the thousand-grain weight of the genotypes and the years. Thousand-grain weight was greater in the first year (29.84 g) than in the second year (26.02 g). Despite the greater total precipitations of the second year, greater precipitations in May of the first year (Fig. 1) during the grain-fill resulted in greater thousand-grain weight in the first year (Fig. 3). Significant variation and high heredity were reported for the thousand-grain weight of the cultivars (Yanming et al. 2006; Mut et al. 2018). Vilaro et al. (2004) reported thousand-grain weight of oat cultivars as between 24.15–43.69 g, Buerstmayr et al. (2007) as between 20.9–38.2 g, and Mut et al. (2016) as between 24.8–41.3 g. The results of the present study agree with the reported values of these studies. For oat grains to be used in human nutrition, a thousand-grain weight should be greater than 25 g (Kahraman et al. 2017). Mut et al. (2018) indicated that thousand-grain weight was an important quality parameter and values mostly varied with the cultivars, years, and climate factors.

Protein Content

Since oat grains are used both in human nutrition and animal feedings, high protein contents are desired in oat farming. Protein contents of the genotypes varied between 8.82–14.81% with an average value of 11.53% in landraces and 11.24% in cultivars. As seen in Figure 2, 124 genotypes were placed into protein content intervals of 10.50–11.50%. Genotype G66 with the greatest protein content stayed out of the normal distribution. A large variation was also observed among genotypes in terms of

Table 2: Analysis of variance of quality traits in oat (mean squares).

	df	SP	TGW	PC	SC	βG	ADF	NDF	FC	18:02	18:01	18:00	16:00
Year (Y)	1	3671.95 **	1949.84**	11.03 **	752.90 **	43.04 **	372.22**	408.26 **	35.54 **	32.97**	660.80**	1.25 **	397.23 **
Genotypes (G)	254	52.46 **	29.62*	3.36 *	14.26	0.14	2.75**	5.18	1.86 **	2.55	6.53	0.01	0.88 **
Y × G İnt.	254	5.09	6.50	0.42 **	6.04	0.05	1.50	2.51	0.21 **	1.05	2.43	0.01	0.55 *
Error	66	14.61	22.95	0.03	17.57	0.33	1.37	4.10	0.02	2.55	8.22	0.01	0.38
CV		4.40	17.09	1.50	9.41	17.95	7.59	6.49	2.39	4.55	7.01	5.62	3.09

* and ** significant at $P < 0.05$ and $P < 0.01$ level, respectively. SP = Screenings percentage (>2.0 mm) (%), TGW = Thousand-grain weight (g), PC = Protein content (%), SC = Starch content (%), βG = β-glucan content (%), ADF = Acid detergent fibre (%), NDF = Neutral detergent fibre (%), FC = Fat content (%), 18:2 = Linoleic acid content (%), 18:1 = Oleic acid content (%), 18:0 = Palmitic acid content (%), 16:0 = Stearic acid content (%), df = Degree of freedom, CV = Variation coefficient.

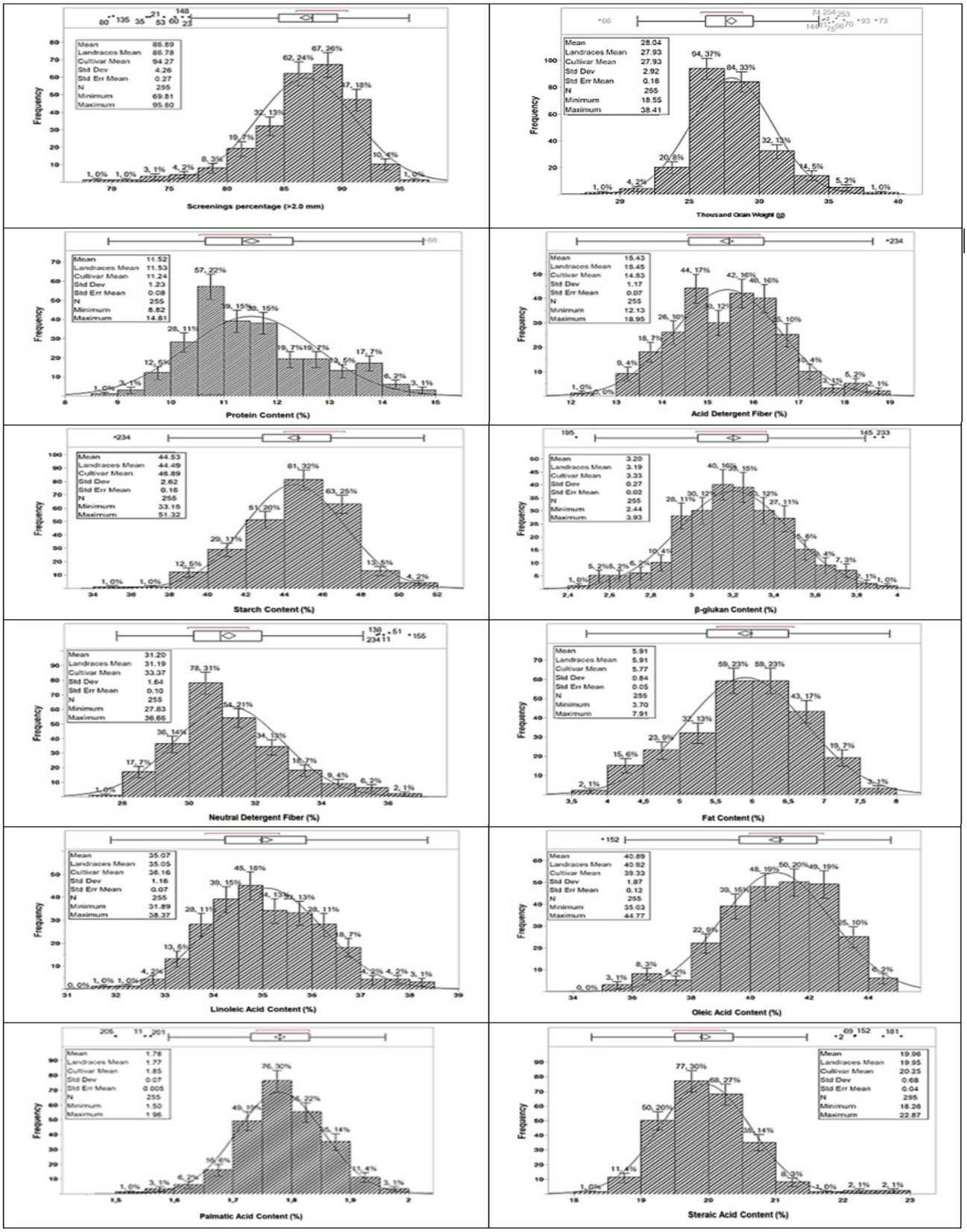

Fig. 2. Histogram graphics and descriptive statistics data showing the studied quality characteristics of 255 oat genotypes (ADF = Acid detergent fiber, NDF = Neutral detergent fiber, 18:2 = Linoleic acid content, 18:1 = Oleic acid content, 18:0 = Palmatic acid content, 16:0 = Steraic acid content, the values were presented in dry weight).

protein content. Landrace genotypes G3, G7, G65, G66, G68, G69, G74, G75, G82, and G89 had the highest protein content (Table 3). Besides the genotype, protein content was also influenced by precipitations, monthly distribution of precipitations, and temperatures. The protein content was lower in the first year (11.39%) than in the second year (11.67%) (Fig. 3). Drier conditions of the second year during the grain-fill period decreased grain weights and then increased protein contents. Mut et al. (2018) indicated that protein content was largely influenced by genotype and environment. Doehlert et al. (2001) indicated that grain protein contents were equally influenced by genetics and environmental factors. In previous studies, protein contents of oat grains were reported as having values between 8.8–14.8% (Dumlupınar et al. 2011; Mut et al. 2016; Mut et al. 2018). It was also reported that populations collected from different locations exhibited genetic differences (Peterson et al. 2005; Yanming et al. 2006).

Starch Content

Starch is an important source of energy in human nutrition and animal feeding. Starch exists in endosperm surrounded by bran layers rich in β-glucan and protein (Punia et al. 2020). The starch contents of the present genotypes varied between 35.15–51.32% with an average value of 44.49% in landraces and 46.89% in cultivars (Fig. 2). 81 genotypes were placed into the starch content interval of 44–46% and the genotype G234 with the lowest starch content stayed out of the normal distribution. Starch content was greater in the first year (45.7%) than in the second year (43.29%) (Fig. 3). The highest starch content was determined in the G15, G16, G34, G65, G66, G73, G78, G93, G144, and G173 genotypes (Table 3). Doehlert et al. (2001) and Mut et al. (2018) indicated that starch contents of the oat genotypes were influenced by the genotypes, environmental factors, and years. In previous studies, starch contents were reported as having values between 45.65–46.28% (Brunava et al. 2014), between 34.9–47.7% (Mut et al. 2016), between 35.6 –52.2% (Sarı et al. 2016), and between 42.7–49.6% (Mut et al. 2018).

Table 3: Top ten genotypes with the desired values in terms of investigated traits.

Traits	Genotypes
SP	G34, G93, G94, G102, G120, G138, G170, G182, G231, G240
TGW	G55, G70, G73, G74, G78, G81, G93, G94, G96, G144
PC	G3, G7, G65, G66, G68, G69, G74, G75, G82, G89
SC	G15, G16, G34, G65, G66, G73, G78, G93, G144, G173
βC	G17, G67, G70, G74, G78, G145, G173, G204, G233, G235
ADF	G25, G30, G32, G55, G56, G104, G134, G137, G170, G206
NDF	G34, G38, G64, G76, G177, G191, G192, G193, G195, G223
FC	G34, G38, G64, G76, G177, G191, G192, G193, G195, G223
18:02	G73, G74, G77, G81, G93, G96, G126, G135, G150, G152
18:01	G8, G92, G141, G154, G177, G195, G205, G214, G245, G248
18:00	G2, G48, G68, G69, G80, G138, G152, G169, G174, G181
16:00	G34, G48, G65, G93, G104, G132, G145, G197, G202, G251

SP = Screenings percentage (>2.0 mm) (%), TGW = Thousand-grain weight (g), PC = Protein content (%), SC = Starch content (%), βG = β-glucan content (%), ADF = Acid detergent fibre (%), NDF = Neutral detergent fibre (%), FC = Fat content (%), 18:2 = Linoleic acid content (%), 18:1 = Oleic acid content (%), 18:0 = Palmitic acid content (%), 16:0 = Stearic acid content (%).

β-glucan Content

The β-glucan contents of the genotypes varied between 2.44–3.93%. 139 genotypes had a β-glucan content interval of 3–3.4% and this interval constituted about 55% of present genotypes. The genotype G195 with a lower β-glucan content than the genotypes G145 and G233 with the greatest β-glucan contents stayed out of the normal distribution (Fig. 2). The average β-glucan content was measured as 3.49% in the first year and 2.92% in the second year (Fig. 3).

Among 255 genotypes, G17, G67, G70, G74, G78, G145, G173, G204, G233, and G235 were in the top ten in terms of the highest β-glucan content (Table 3). Doehlert et al. (2001) indicated that β-glucan content was largely influenced by the genotypes and Mut et al. (2018) indicated that β-glucan content was influenced by environment and agronomic treatments. In previous studies, β-glucan contents of oat grains were reported as having values between 2.38–5.07% (Martinez et al. 2010; Brunova et al. 2014; Mut et al. 2018). The β-glucans of oat grain strengthen the immune system in humans and reduce blood glucose levels (Tiwari and Cummins 2009). They are also used in cosmetics, food, and pharmaceuticals (Kamboj et al. 2020). Due to these beneficial characteristics, β-glucan has always been a selection criterion in oat breeding programs.

Acid Detergent Fiber (ADF)

The ADF values of the genotypes varied between 12.13–18.95%. The average ADF value was greater in landraces (15.45%) than in the cultivars (14.53%). According to Figure 2, 207 genotypes were placed into an ADF interval of 14–17% and the genotype G234 with a high ADF value stayed out of the normal distribution. The average ADF value was measured as 14.59% in the first year and 16.3% in the second year. Low ADF values indicate high feed quality (Van Dyke and Anderson 2000). G25, G30, G32, G55, G56, G104, G134, G137, G170, and G206 had the lowest ADF values in this study (Table 3). Mut et al. (2018) indicated that ADF contents were influenced by genotype and environment, and reported ADF values of between 14.2–16.4%.

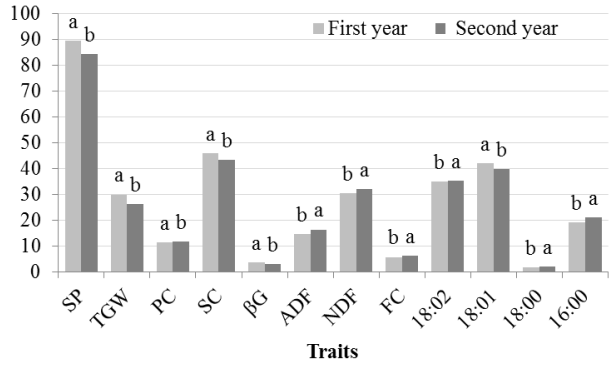

Fig. 3. Mean values for quality traits of oat genotypes for two years. Bars not accompanied by the same letter are significantly different at $P < 0.05$ using Tukey's HSD test. (The values were presented in dry weight).

Neutral Detergent Fiber (NDF)

The NDF values of the genotypes varied between 27.8–36.66%. The average NDF value was lower in landraces (31.19%) than the cultivars (33.37%). According to Figure 2, 78 genotypes were placed into an NDF interval of 30–21% and the genotypes G11, G51, G138, G155, and G234 stayed out of the normal distribution. The average NDF value was measured as 30.3% in the first year and 32.09% in the second year. For optimum yields, the NDF values should be between 25–32% (Tekce and Gül 2014). Mut et al. (2018) indicated that NDF contents were largely influenced by genotype and environment, and reported feed NDF values between 31.5–34.4%. Biel et al. (2020) reported that ADF and NDF contents of hulled oat genotypes ranged between 15.6–18.4% and 29.7–38.0%. They also reported that the average ADF and NDF contents of hulled oats were higher than the other examined cereals.

Fat Content

In this study, it was determined that the fat content showed a wide variation. Grain fat contents of the genotypes varied between 3.70–7.91%. Fat contents of the collected landraces exhibited continuous and normal distribution and 108 genotypes were placed into the fat content interval of 5.5–6.5% (Fig. 2). The average fat content was measured as 5.91% in landraces and 5.77% in cultivars. Fat content was lower in the first year (5.65%) than in the second year. Genotypes G34, G38, G64, G76, G177, G191, G192, G193, G195, and G223 were the top ten genotypes with the highest fat content (Table 3). Saastamoinen et al. (1989) indicated that fat contents were influenced by genotype and environmental factors and reported fat contents of oat grains between 3–12%. Fats are energy sources and constitute key components of cell membranes (de Oliveira Maximino et al. 2020). As compared with the other small grain cereals, oat fat is quite rich in unsaturated fatty acids (Carlson et al. 2019). High fat contents are preferred when the oat grains are to be used in animal feeding (Martinez et al. 2010), but low fat contents are preferred when the grains are to be used in human nutrition (Doehlert et al. 2001). In previous studies, Martinez et al. (2010) reported fat contents between 3.1–11.6%, Mut et al. (2016) between 5.86–8.47%, and Bityutskii et al. (2019) between 2.7–8.1%.

Fatty Acid Contents

Linoleic acid contents of the genotypes varied between 31.89–38.37%, oleic acid contents between 35.03–44.77%, palmitic acid contents between 18.26–22.87%, and stearic acid contents between 1.50–1.96% (Fig. 2). The greatest number of genotypes was placed in an interval of 34.5–35.0% for linoleic acid (45 genotypes); 40.0–42.5% for oleic acid (147 genotypes); 19.5–20.0% for palmitic acid (77 genotypes); and 1.75–1.80% for stearic acid (76 genotypes). The top ten genotypes with the highest fatty acid contents are shown in Table 3. Besides greater fat contents than the other small grain cereals, oat grains are also rich in unsaturated fatty acids. Oleic, linoleic, and palmitic acids constitute about 90–95% of fatty acid composition of oat grains (Saastamoinen et al. 1989; Zhou et al. 1998; Martinez et al. 2010). Zhou et al. (1998) reported oleic acid contents of oat grains between 37.9–42.6%, linoleic acid contents between 35.9–39.9%, and palmitic acid contents between 17.0–19.3%. Moreover, they indicated that genotypes had greater effects on fatty acid composition than the environmental factors. Dhanda (2011) indicated that fatty acid composition was largely dominated by genotype, but palmitic and oleic acid contents were also largely influenced by environmental factors. Oat fatty acids were reported to have beneficial effects on heart health, cancer, diabetes, and neurologic disorders (Bityuskii et al. 2020). For these reasons, oat is considered as high-quality nutritional food and thus is gaining popularity among nutritionists.

Biplot Analysis

Biplot analysis was conducted for visual presentation of the relationships among the genotypes and traits. The biplot analysis generally yields better outcomes than the correlation analysis revealing the relationships only between two genotypes (Yan and Frégeau-Reid 2008). The PCA was applied to identify the traits which were the main source of the variability and to explain the genetic diversity among genotypes. The relationship between genotypes and investigated traits is shown in Figure 4A. According to the biplot analysis, PC1 explained 24.4% and PC2 explained 20.2% of the total population (both

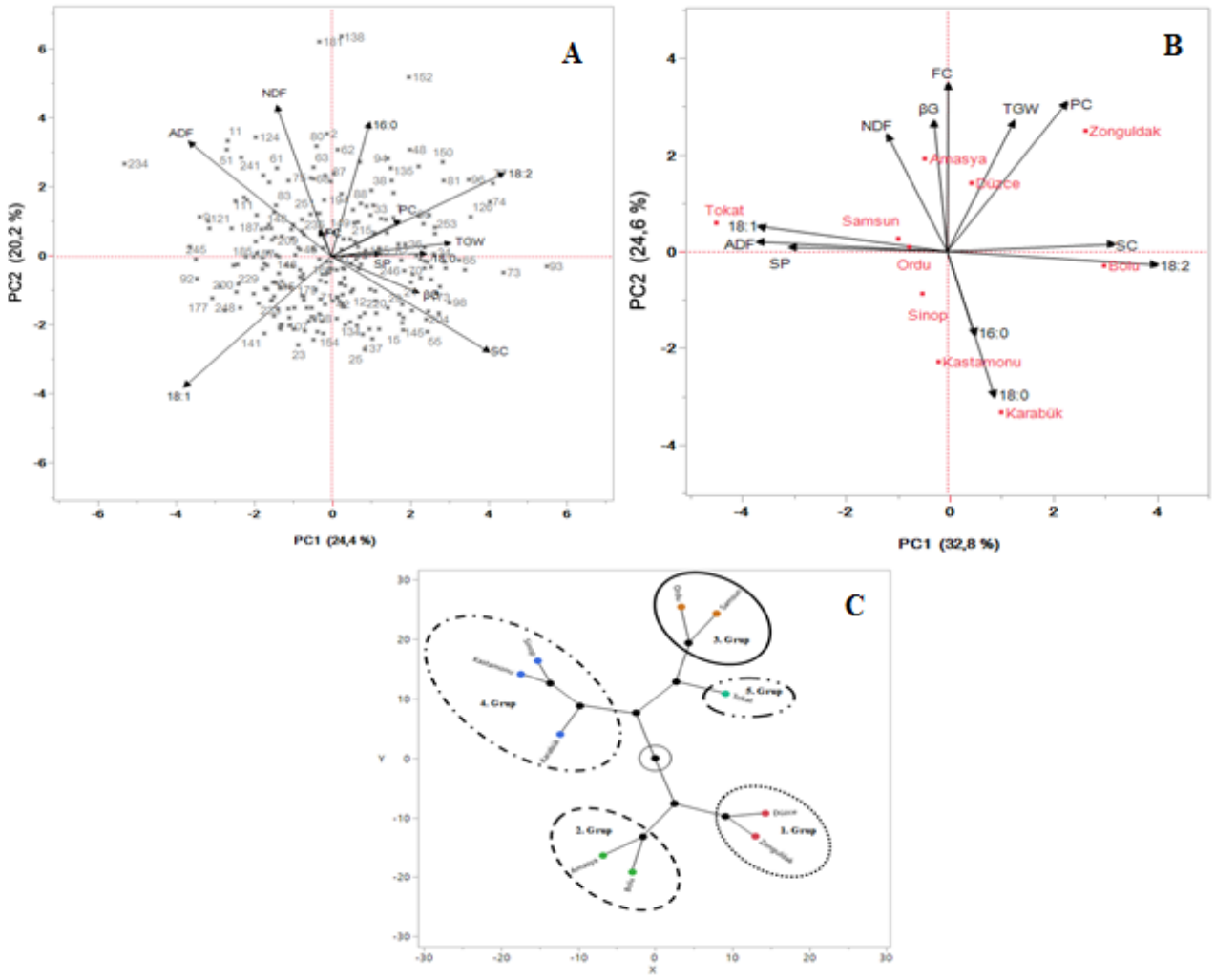

Fig. 4. The grouping of the studied traits by biplot analysis method and A) genotype by trait (GT) biplot based on the original genotype by means of trait data (transform = 0, scaling = 0, centering = 2, SVP = 2); B) the relation of collected provinces with the discussed features; C) Grouping of areas collected according to the examined traits with the constellation plot.

explained 44.6% of total variation) (Fig. 4A). Two traits are positively correlated if the angle between the vectors is acute (<90°), negatively correlated if the angle is obtuse (>90°), and not correlated if the angle is a right angle (Yan and Tinker 2006). The vectors of stearic acid content, screenings percentage, thousand-grain weight, linoleic acid content, protein content, and palmitic acid content were placed on the upper right section of the biplot and since the angle between these traits was smaller than 90°, there were significant positive relationships between these traits. The vector of oleic acid content acted in a reverse direction of these traits and thus had negative relationships with them. The vectors of ADF value, NDF value, and oil content were placed on the upper left section of the biplot and had positive relationships between them. The vectors of starch and β-glucan contents with negative relationships with these traits were placed on the lower right section of the biplot and had negative relationships between them (Fig. 4A). Since the vectors of ADF, NDF, palmitic acid, linoleic acid, starch, and oleic acid traits were longer than the vectors of oil content, protein content, screenings percentage, stearic acid, and β-glucan traits, they better represented the population. The ten genotypes with the highest values in terms of SP, TGW, PC, SC, βG, FC, 18:2, 18:1, 18:0, and 16:0 traits and the lowest values in terms of ADF and NDF are shown in Table 3.

The genotypes were grouped based on the provinces from where they were collected and were subjected to biplot analysis (Fig. 4B). Analysis revealed that PC1 constituted 32.8% and PC2 constituted 24.6% of the total variation (both representing 57.4% of the total variation).

Some provinces where the genotypes were collected were near the center of the biplot. Therefore, genotypes collected from these provinces were prominent in terms of more than one trait. Since there is an acute angle between the NDF, β-glucan, fat, thousand-grain weight, and protein traits of the genotypes collected from Amasya, Düzce, and Zonguldak provinces, these genotypes were prominent in terms of the traits (Fig. 4B).

Genotypes whose origin in Bolu province were prominent for starch and linoleic acid; genotypes whose origins are Kastamonu and Karabük provinces were prominent for palmitic and stearic acid content; and genotypes whose origins are Sinop, Ordu, Samsun, and Tokat provinces were prominent for screenings percentage, ADF, and oleic acid traits (Fig. 4B).

According to the constellation graph of the genotypes based on provinces from where they were collected, provinces were divided into two main groups for investigated traits, and these main groups were divided into five sub-groups. Zonguldak and Düzce provinces were placed in the first group, Amasya and Bolu provinces in the second group, Ordu and Samsun provinces in the third group, Sinop, Kastamonu, and Karabük provinces in the fourth group, and Tokat province in the fifth group. Except for the second group, all groups were composed of neighboring provinces (Fig. 4C). The area covering especially Amasya, Samsun, and Tokat provinces constitutes one of five micro gene centers of Turkey (Şehirali et al. 2005). In this sense, it was considered that there were significant genetic differences among the collected local genotypes. It is reported that landraces with high quality values are very valuable gene resources for use in oat breeding programs. These genotypes can also be released as potential cultivars for production.

CONCLUSION

This study was carried out to determine the quality traits of many different oat landraces collected from different provinces whose quality characteristics were not known before. Present findings showed a great variation in screenings percentage >2 mm, thousand grain weight, protein, starch, β-glucan, acid detergent fibre, neutral detergent fibre, fat, linoleic acid, oleic acid, palmitic acid, and stearic acid values of oat landraces. Statistical analyses on physico-chemical quality traits of the collected oat landraces revealed that the present material had quite a rich genetic base. Majority of oat landraces had superior investigated quality traits than the standard cultivars. The genotype-trait biplot is an excellent tool used to visualize correlations between quality traits and is recommended for the reliable identification of oat landraces able to present high quality traits. The results of the study indicated that the majority of landraces can be used as both selection and hybridization materials in further breeding programs.

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Table S1. Locations and local cultivars of collected samples in Turkey.

Number	Province	Country	Village	Latitude	Longitude	Altitude
1	Düzce	Center	Center	40.48 44	31.08 20	143
2	Düzce	Center	Turalpler	40.49 28	31.08 55	142
3	Düzce	Center	Darıca	40.49 24	31.08 54	147
4	Düzce	Center	Ballıca	40.46 44	31.06 58	143
5	Düzce	Center	Darıca	40.49 24	31.08 54	147
6	Düzce	Kaynaşlı	Center	40.47 23	31.15 38	228
7	Düzce	Kaynaşlı	Center	40.46 42	31.17 52	272
8	Düzce	Çilimli	Esenli	40.52 19	31.06 15	139
9	Düzce	Çilimli	Esenli	40.52 17	31.06 05	139
10	Düzce	Gümüşova	Yeşilyayla	40.47 41	30.52 02	130
11	Düzce	Gölyaka	Center	40.46 12	29.56 17	125
12	Bolu	Center	Kızılağıl	40.46 14	31.59 44	988
13	Bolu	Center	Avdan	40.48 30	31.50 10	950
14	Bolu	Center	Belkarağa	40.35 30	31.45 40	970
15	Bolu	Center	Center	40.33 20	31.52 16	890
16	Bolu	Center	Kızılağıl	40.46 14	31.59 44	988
17	Bolu	Center	Alıçören	40.40 00	31.34 30	820
18	Bolu	Center	Saççılar	40.38 20	31.20 40	850
19	Bolu	Center	Yazıköy	40.37 00	31.30 30	940
20	Bolu	Mudurnu	Uzunçam	40.23 42	31.05 47	1161
21	Bolu	Mudurnu	Çepni	40.33 15	31.15 04	871
22	Bolu	Mudurnu	Sarıyer	40.33 13	31.15 40	876
23	Bolu	Mudurnu	Sürmeli	40.30 20	31.13 23	790
24	Bolu	Mudurnu	Uzunçam	40.23 49	31.05 34	1179
25	Bolu	Mudurnu	Samat	40.33 45	31.17 49	940
26	Bolu	Mudurnu	Center	40.26 39	31.11 23	929
27	Bolu	Mudurnu	Uzunçam	40.23 55	31.17 48	955
28	Bolu	Mudurnu	Sürmeli	40.30 20	31.12 09	779
29	Bolu	Mudurnu	Karaardıç	40.18 36	30.50 56	710
30	Bolu	Mudurnu	Tekirler	40.17 45	31.01 40	1047
31	Bolu	Mudurnu	Dağhacılar	40.16 43	30.57 54	1028
32	Bolu	Mudurnu	Alanköy	40.22 56	30.58 39	1169
33	Bolu	Mudurnu	Ahmetbeyler	40.17 46	30.48 34	548
34	Bolu	Mudurnu	Center	40.23 50	30.47 29	754
35	Bolu	Mudurnu	Yeniköy	40.19 57	30.55 52	844
36	Bolu	Mudurnu	Yeniköy	40.19 28	30.48 55	992
37	Bolu	Mudurnu	Bekirfakiler	40.22 44	30.58 58	1099
38	Bolu	Mudurnu	Dağşeyhler	40.16 52	30.59 33	992
39	Bolu	Mudurnu	Aksaklar	40.17 55	30.57 48	1178
40	Bolu	Mengen	Kayabaşı	40.53 48	32.05 04	988
41	Bolu	Mengen	Elemen	40.55 27	31.50 20	955
42	Bolu	Mengen	Kayabükü	40.55 40	32.20 15	995
43	Bolu	Mengen	Center	40.57 59	32.05 50	975
44	Bolu	Seben	Susuz	40.20 37	31.34 34	1035
45	Bolu	Seben	Kesenözü	40.18 59	31.32 50	804
46	Bolu	Seben	Algoluk	40.24 45	31.36 07	829
47	Bolu	Seben	Center	40.25 10	31.34 47	784
48	Bolu	Gerede	Ibrıcak	40.47 32	31.07 57	1022
49	Bolu	Gerede	Center	40.53 25	31.20 20	1230
50	Bolu	Dörtdivan	Göcükler	40.45 58	31.06 05	830

Table S1. (Continuation...)

Number	Province	Country	Village	Latitude	Longitude	Altitude
51	Bolu	Yeniçağa	Saray	40.44 54	31.23 00	764
52	Bolu	Yeniçağa	Doğancı	40.46 57	32.05 56	1019
53	Zonguldak	Center	Dağköy	41.20 04	31.40 42	545
54	Zonguldak	Center	Kabalaklı	41.18 52	31.42 09	521
55	Zonguldak	Center	Kozlu	41.11 05	31.28 09	201
56	Zonguldak	Center	Karapınar	41.18 00	31.42 24	337
57	Zonguldak	Center	Kozlu	41.18 00	31.42 16	371
58	Zonguldak	Center	Dağköy	41.20 03	31.40 42	554
59	Zonguldak	Center	Himmetoğlu	41.21 55	31.40 34	351
60	Zonguldak	Center	Saka	41.21 05	31.40 41	374
61	Zonguldak	Center	Taşmacı	41.20 18	31.40 45	600
62	Zonguldak	Ereğli	Center	41.16 04	31.30 58	116
63	Zonguldak	Ereğli	Soğanlıyörük	41.15 57	31.31 19	35
64	Zonguldak	Ereğli	Esentepe	41.31 12	31.37 53	120
65	Zonguldak	Ereğli	Kızılcapınar	41.14 10	31.36 16	79
66	Zonguldak	Ereğli	Vakif	41.14 40	31.50 21	457
67	Zonguldak	Ereğli	Vakif	41.15 00	31.57 20	487
68	Zonguldak	Ereğli	Doğan	41.15 45	31.30 59	15
69	Zonguldak	Ereğli	Yalnızçam	41.18 20	31.38 30	450
70	Zonguldak	Ereğli	Pınarcık	41.16 18	31.32 14	16
71	Zonguldak	Ereğli	Kızılcapınar	41.14 21	31.36 13	67
72	Zonguldak	Ereğli	Sakallar	41.13 58	31.51 38	694
73	Zonguldak	Ereğli	Külah	41.12 32	31.39 02	244
74	Zonguldak	Ereğli	Esentepe	41.13 12	31.37 53	120
75	Zonguldak	Ereğli	Yazıcılar	41.15 19	31.35 47	25
76	Zonguldak	Ereğli	Pınarcık	41.16 18	31.32 14	16
77	Zonguldak	Çaycuma	Başaran	41.32 50	32.04 00	45
78	Zonguldak	Çaycuma	Karapınar	41.30 59	32.15 20	30
79	Zonguldak	Çaycuma	Veliköy	41.27 43	32.06 10	65
80	Zonguldak	Çaycuma	Karapınar	41.30 55	32.15 00	55
81	Zonguldak	Çaycuma	Kadıoğlu	41.25 58	32.06 10	252
82	Zonguldak	Çaycuma	Başaran	41.42 50	32.04 00	45
83	Zonguldak	Çaycuma	Aliköy	41.24 20	32.03 30	85
84	Zonguldak	Çaycuma	Kayılar	41.36 24	32.20 20	78
85	Zonguldak	Devrek	Özpınar	40.54 44	31.54 22	628
86	Zonguldak	Devrek	Özpınar	41.09 44	31.54 14	215
87	Zonguldak	Devrek	Özpınar	41.09 44	31.54 14	215
88	Zonguldak	Devrek	Yazıcık	41.01 56	31.54 46	336
89	Zonguldak	Devrek	Tabaklar	41.15 10	31.58 20	272
90	Zonguldak	Devrek	Yazıcık	41.02 55	31.59 02	369
91	Zonguldak	Devrek	Yeşilada	41.06 01	31.49 01	192
92	Zonguldak	Devrek	Yazıcık	41.01 56	31.54 46	336
93	Zonguldak	Gökçebey	Center	41.35 45	32.16 18	80
94	Zonguldak	Gökçebey	Bakiler	41.20 55	32.04 00	65
95	Zonguldak	Gökçebey	Çukur	41.20 30	32.40 10	70
96	Zonguldak	Alaplı	Abdi	41.11 02	32.29 33	223
97	Zonguldak	Alaplı	Abdi	41.11 05	32.29 09	201
98	Zonguldak	Alaplı	Gevrek	41.13 20	32.36 19	70
99	Zonguldak	Alaplı	Gökhasan	41.11 34	32.36 16	132
100	Karabük	Center	Hocaköprüsü	40.08 02	32.47 21	381

Table S1. (Continuation...)

Number	Province	Country	Village	Latitude	Longitude	Altitude
101	Karabük	Safranbolu	Yukarıçiftlik	41.17 27	32.43 18	819
102	Karabük	Safranbolu	Center	41.12 16	32.52 44	383
103	Karabük	Safranbolu	Düzce	41.16 04	32.42 35	780
104	Karabük	Safranbolu	Yazı	41.14 36	31.44 28	503
105	Karabük	Eskipazar	Çaylı	40.54 42	32.29 09	988
106	Karabük	Eskipazar	Ova	40.58 55	32.31 34	769
107	Karabük	Eskipazar	Hamzalar	40.54 32	32.26 26	1050
108	Karabük	Eskipazar	Kabaarmut	40.54 04	32.24 59	1261
109	Karabük	Ovacık	Ganibeyler	40.07 04	32.53 44	563
110	Karabük	Ovacık	Çukurköy	41.07 04	32.49 29	632
111	Karabük	Ovacık	Boyalı	40.25 53	32.44 58	528
112	Kastamonu	Center	Kurusaray	40.28 56	33.51 12	766
113	Kastamonu	Center	Çavundur	40.28 46	33.58 49	627
114	Kastamonu	Center	Kurusaray	41.28 20	33.53 16	672
115	Kastamonu	Center	Çavundur	41.29 24	33.58 55	638
116	Kastamonu	Center	Center	41.27 02	33.51 57	757
117	Kastamonu	Center	Center	41.27 03	33.51 45	743
118	Kastamonu	Devrekani	Yukarıbatak	41.50 05	33.59 40	810
119	Kastamonu	Devrekani	Bozoğlak	41.55 10	33.55 00	800
120	Kastamonu	Devrekani	Belovacık	41.34 20	33.59 45	1210
121	Kastamonu	Araç	Güllükler	41.12 58	33.00 05	518
122	Kastamonu	Araç	Vakıfakkeçi	41.12 55	33.57 07	473
123	Kastamonu	Araç	Yukarıoba	41.11 20	33.14 50	930
124	Kastamonu	Araç	Güzelce	41.15 56	33.57 44	851
125	Kastamonu	Taşköprü	Center	41.30 31	34.09 49	570
126	Kastamonu	Taşköprü	Uzunköprü	41.29 25	33.39 50	630
127	Kastamonu	Taşköprü	Uzunkavak	41.29 24	33.59 54	620
128	Kastamonu	Taşköprü	Uzunkavak	41.29 28	33.59 47	635
129	Kastamonu	Taşköprü	Aşağısağırcı	41.30 29	33.09 49	578
130	Kastamonu	Daday	Uzbanlar	41.30 30	33.34 00	820
131	Kastamonu	Daday	Sarıçam	41.29 45	33.47 40	790
132	Kastamonu	Hanönü	Sirke	41.36 45	34.21 53	498
133	Kastamonu	Hanönü	Gökçeağaç	41.38 00	34.30 40	482
134	Kastamonu	Hanönü	Center	41.37 40	34.26 29	461
135	Kastamonu	Seydiler	Center	41.38 20	33.42 40	1010
136	Kastamonu	Küre	Camili	41.48 55	33.50 14	1000
137	Kastamonu	İhsangazi	Center	41.13 16	33.27 38	832
138	Kastamonu	İhsangazi	Center	41.16 10	33.20 30	845
139	Kastamonu	İnebolu	Başköy	41.56 12	33.46 20	400
140	Kastamonu	İnebolu	Başköy	41.55 02	33.38 35	615
141	Kastamonu	Çatalzeytin	Başköy	42.00 00	34.10 20	625
142	Ordu	Akkuş	Yenikonak	40.52 34	37.20 20	1100
143	Ordu	Akkuş	Çayıralan	40.51 20	37.05 10	940
144	Ordu	Kumru	Center	40.50 24	37.15 10	480
145	Ordu	Çaybaşı	Göksu	41.04 10	37.10 05	1020
146	Ordu	Aybastı	Çakırlı	40.40 22	37.22 54	1100
147	Ordu	Korgan	Belalan	40.46 50	37.16 10	1025
148	Sinop	Center	Yuvalı	41.48 00	35.24 00	140
149	Sinop	Center	Yenikent	41.46 20	35.20 10	230
150	Sinop	Center	Yaykıl	41.50 00	35.07 10	135

Table S1. (Continuation...)

Number	Province	Country	Village	Latitude	Longitude	Altitude
151	Sinop	Erfelek	İneseki	41.53 55	34.55 22	183
152	Sinop	Erfelek	İneşekü	41.53 38	34.55 41	141
153	Sinop	Erfelek	İncirpınar	41.59 41	34.53 22	110
154	Sinop	Erfelek	İnesökü	41.53 38	34.55 41	145
155	Sinop	Erfelek	Karacaköy	41.55 48	34.55 40	140
156	Sinop	Durağan	Köklen	41.11 17	35.08 12	400
157	Sinop	Durağan	Sofular	41.22 13	35.12 35	420
158	Sinop	Durağan	Center	41.24 59	35.03 23	217
159	Sinop	Durağan	Center	41.19 05	35.11 14	217
160	Sinop	Gerze	Yamacık	41.44 10	35.11 31	560
161	Sinop	Gerze	Yamacık	41.44 03	35.11 40	483
162	Sinop	Gerze	Abdaloğlu	41.47 39	35.09 46	275
163	Sinop	Gerze	Bolalı	41.41 40	35.09 01	638
164	Sinop	Ayancık	Hatip	41.52 40	34.42 10	450
165	Sinop	Saraydüzü	Aşağıbaşhekim	41.34 30	34.57 20	360
166	Sinop	Saraydüzü	Cumaköy	41.20 41	34.47 10	470
167	Sinop	Dikmen	Üçpınar	41.34 36	35.18 16	751
168	Sinop	Dikmen	Üçpınar	41.33 59	35.18 18	630
169	Samsun	Center	Gecehan	41.08 08	36.16 03	634
170	Samsun	Center	İmamlar	41.08 35	36.20 18	730
171	Samsun	Center	Çamalan	41.07 49	36.19 07	647
172	Samsun	Center	Çamalan	41.08 49	36.22 42	672
173	Samsun	Center	Center	41.22 18	36.14 30	185
174	Samsun	Asarcık	Hisariye	41.01 56	36.09 59	780
175	Samsun	Asarcık	Musaağa	41.04 31	36.14 17	748
176	Samsun	Asarcık	Esentepe	41.01 11	36.08 33	618
177	Samsun	Asarcık	Kuşca	41.00 54	36.09 27	653
178	Samsun	Vezirköprü	Başpınar	41.07 57	35.12 06	717
179	Samsun	Vezirköprü	Yolsarınçlı	41.10 41	35.16 23	274
180	Samsun	Vezirköprü	Pazarcı	41.04 29	35.29 53	687
181	Samsun	Vezirköprü	Adatepe	41.09 49	35.27 17	275
182	Samsun	Vezirköprü	Yeniçelik	41.03 38	35.30 24	667
183	Samsun	Vezirköprü	Öğürlü	41.06 39	35.10 02	710
184	Samsun	Ladik	Budakdere	40.57 35	36.07 54	781
185	Samsun	Ladik	Salur	40.59 58	35.53 54	840
186	Samsun	Ladik	Söğütlü	40.54 51	35.46 57	923
187	Samsun	Ladik	Kuyucak	40.55 12	35.46 56	920
188	Samsun	Ladik	İbi	40.58 14	35.53 91	850
189	Samsun	Tekkeköy	Çınaralan	41.11 21	36.26 46	340
190	Samsun	Tekkeköy	Köprübaşı	41.11 57	36.30 32	20
191	Samsun	Tekkeköy	Çınaralan	41.11 19	36.26 20	407
192	Samsun	Tekkeköy	Kutlukent	41.05 16	36.13 20	713
193	Samsun	Tekkeköy	Kutlukent	41.15 10	36.20 20	155
194	Samsun	Ayvacık	Ardıç	41.04 00	36.37 05	550
195	Samsun	Ayvacık	Çarşıköy	41.03 00	36.42 00	610
196	Samsun	Ayvacık	Gültepe	40.55 35	36.30 40	780
197	Samsun	Çarşamba	Gürpınar	41.13 09	36.37 16	20
198	Samsun	Çarşamba	Çaydar	41.08 42	36.41 59	90
199	Samsun	Çarşamba	Center	41.12 20	36.44 10	22
200	Samsun	Alaçam	Center	41.28 00	35.30 10	50

Table S1. (Continuation...)

Number	Province	Country	Village	Latitude	Longitude	Altitude
201	Samsun	Alaçam	Kızlan	41.10 05	35.10 00	850
202	Samsun	Alaçam	Umutlu	41.27 23	35.32 30	1028
203	Samsun	Bafra	Meşelitürkmen	41.15 03	35.52 28	937
204	Samsun	Bafra	Akalan	41.19 09	35.42 32	1020
205	Samsun	Havza	Center	40.58 59	36.54 56	705
206	Samsun	Havza	Çakıralan	41.10 49	35.45 38	852
207	Samsun	Havza	Şeyler	41.11 02	35.52 32	829
208	Samsun	Kavak	Ahırlı	41.04 02	35.58 59	620
209	Samsun	Kavak	Bekdemir	41.01 44	36.06 53	537
210	Samsun	Kavak	Dereköy	41.05 16	35.53 07	1006
211	Samsun	Kavak	Akbelen	41.10 02	35.53 29	839
212	Samsun	Kavak	Bekdemir	41.01 44	36.06 53	537
213	Samsun	Kavak	Ahırlı	41.04 04	35.59 11	603
214	Samsun	Kavak	Akbelen	41.10 25	35.52 50	841
215	Samsun	Kavak	Akbelen	41.10 20	35.58 33	710
216	Samsun	Salıpazarı	Tahnal	40.55 40	36.47 40	1100
217	Amasya	Center	Center	40.35 10	35.49 00	520
218	Amasya	Taşova	Korubaşı	40.56 54	36.12 03	946
219	Amasya	Taşova	Korubaşı	40.56 51	36.12 14	977
220	Amasya	Taşova	Destek	40.50 58	36.10 31	977
221	Amasya	Taşova	Destek	40.50 58	36.10 31	977
222	Amasya	Gümüşhacıköy	Gümüş	40.50 20	35.15 00	880
223	Amasya	Gümüşhacıköy	Balıklı	40.32 10	35.18 14	980
224	Amasya	Suluova	Soku	40.51 40	35.51 36	1166
225	Amasya	Suluova	Bayırlı	40.50 56	35.43 51	781
226	Amasya	Suluova	Derebaşalan	40.51 57	35.49 30	1059
227	Amasya	Merzifon	Kayadüzü	40.53 20	35.32 50	710
228	Amasya	Merzifon	Selimiye	40.40 09	35.28 40	910
229	Amasya	Merzifon	Center	40.52 00	35.27 32	740
230	Amasya	Hamamözü	Yeniköy	40.47 53	35.10 45	980
231	Tokat	Center	Keşlik	40.15 59	36.23 07	1131
232	Tokat	Center	Yatmış	40.07 11	36.28 58	1130
233	Tokat	Center	Doruğa	40.02 29	36.22 56	1124
234	Tokat	Center	Yatmış	40.06 48	36.28 40	1120
235	Tokat	Center	Yatmış	40.07 15	36.32 10	1120
236	Tokat	Center	Cumaköy	40.22. 21	36.32 27	900
237	Tokat	Erbaa	Center	40.40 59	36.33 20	620
238	Tokat	Erbaa	Center	40.40 45	36.33 43	700
239	Tokat	Niksar	Center	40.35 34	36.57 40	400
240	Tokat	Niksar	Center	40.35 34	36.57 40	400
241	Tokat	Niksar	Akıncı	40.26 30	37.10 20	560
242	Tokat	Artova	Boyunpınar	40.09 52	36.23 54	1254
243	Tokat	Artova	Center	40.06 58	36.18 08	1171
244	Tokat	Artova	Center	40.06 58	36.18 08	1171
245	Tokat	Artova	Taşpınar	40.12 20	36.17 20	1280
246	Tokat	Yeşilyurt	Kavunluk	40.01 39	36.29 34	1127
247	Tokat	Yeşilyurt	Sivri	40.00 15	36.22 13	1424
248	Tokat	Almus	Ataköy	40.26 52	36.54 54	1180
249	Tokat	Almus	Center	40.22 50	36.54 25	1000
250	Tokat	Zile	Ağılcık	40.17 11	35.35 20	1120
251	Tokat	Reşadiye	Çevrecik	40.26 39	37.12 36	962