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Development and analysis of initial material of winter spelt wheat (*Triticum aestivum* L. ssp. *spelta*) for productivity breeding

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Abstract. In the studies of 2019–2024, the productivity indicators of the starting material of winter spelt wheat, created by hybridization with soft winter wheat at Uman National University (Right-Bank Forest-Steppe of Ukraine), were analyzed. In the process of research, spelt wheat samples were identified that can be used in practical selection as donors of genes for certain traits, in particular, high yield (5.25–5.82 t ha^{-1}); semi-dwarfism and low-stemming in breeding for plant height reduction (samples 1786, 1817, 1559, 1674 and 1755; improved grain threshing (91%) and optimal spike structure (samples 95, 155, 1725); high grain protein content (23.8–28.7%), gluten (49.1–57.2%), alveograph indicator (340–425 alveograph units), grain hardness (60.8–68.2 instrument units) in breeding for grain quality (samples 13, 40 and 128). The correlation between productivity indicators was analyzed and it was found that the greatest influence on spelt yield is the quality of grain threshing ($r = 0.89 \pm 0.00$).

Key words: spelt wheat, plant height, threshing quality, yield, grain quality.

INTRODUCTION

Spelt (*T. aestivum* L. ssp. *spelta*) is one of the oldest species of emmer wheat, known as early as 7–8 millennia BC (Babenko et al., 2018). The phylogeny of spelt is a controversial issue. By origin, it is divided into two subspecies of independent origin: European (supraconvar. *spelta*) and Asian (supraconvar. *kuckuckianum* Gökg. ex Dorof.) (Nesbitt, 2001; Poltoretskyi et al, 2018). Scientists consider the Asian subspecies of spelt to be the oldest hexaploid species of wheat and, probably, the ancestor of soft wheat, which was formed in the 6th millennium BC in Iraq by spontaneous hybridization of the species *Triticum turgidum* ssp. *dicoccon* i *Aegilops Tauschii* ssp. *strangulata* (Kuckuck & Schiemann, 1957; Fans et al, 2006). The emergence of European spelt subspecies in Central and Eastern Europe dates back to the Bronze Age (3rd millennium BC) (Poltoretskyi et al, 2018).

With the advent of naked-grain wheat species, spelt gradually disappeared from cultivated crops. The reason for this was its significantly lower yield, which is due to the low quality of threshing. Currently, the demand for spelt is growing and spelt ranks third among wheats in terms of sown areas. It began to be intensively grown in France, Austria, Israel, Italy, the USA, Australia, Germany, etc. (Alvarez & Guzmán, 2018; Bradna et al, 2019; Suchowilska, 2020). The interest in spelt is due to a number of positive characteristics, in particular, it is a valuable dietary nutrient, characterized by a high grain protein content (up to 25%) balanced in amino acid composition (Dvořāček et al, 2002; Arzani & Ashraf, 2017; Diordiieva et al, 2024). Spelt has the highest grain protein content among hexaploid wheat species, exceeding in this indicator the species *T. aestivum* L. ssp. *aestivum* by 5–10%, *T. aestivum* L. ssp. *sphaerococum* Persiv. by 3–8%, *T. aestivum* L. ssp. *compactum* Host. by 4–5%, *T. petropavlovskyi* Udacz. et Migusch by 2–6% (Arzani & Ashraf, 2017). It is characterized by a high biological value of protein, exceeding soft and durum wheat in the content of essential amino acids, in particular, tryptophan by 10–15% and 15–20%, respectively (Dvořāček et al, 2002).

Spelt wheat breeding is currently being carried out in Ukraine, Switzerland, Austria, Hungary, Germany and Serbia. However, the crop range is limited by a small number of varieties and forms of local selection. Spelt remains a rare species that requires selection improvement. The relatively low yield (approximately 4.0–4.5 t ha^{-1}) and poor threshability of the grain (about 70–75%) are the main limitations for the large-scale adoption of spelt in agricultural production (Babenko et al, 2018; Diordiieva et al, 2024). In this regard, the current task of crop breeding is to increase the yield and quality of grain threshing while maintaining a high content of protein and gluten in the grain. This can be achieved by involving related species of the genus *Triticum* L., in particular *T. Aestivum* L. ssp. *aestivum*, in the hybridization system as donors of genes for individual productivity indicators. By hybridizing the species *T. aestivum* ssp. *spelta* and *T. aestivum* L. ssp. *aestivum*, new transgressive forms of spelt with improved quantitative and qualitative productivity indicators can be obtained.

The purpose of the research was to create and analyze the starting material of winter spelt wheat by hybridization with soft wheat to isolate promising genotypes and involve them in the breeding process of obtaining highly productive crop varieties.

MATERIALS AND METHODS

The research was conducted in the conditions of the Right-Bank Forest-Steppe of Ukraine (Uman town), subzone with unstable moisture conditions (there are droughts once in 2–3 years). The climate of the region is temperate continental. The average long-term precipitation rate for the region is 586 mm, the average annual air temperature is + 8.8 °C. The studies used the generally accepted technology for growing winter grain crops. Sowing was carried out at the optimal time for the zone – the third decade of September. A systematic method of plots placement was used in the research. The numbers were arranged in blocks with every fifth number being a standard. The standard was the winter spelt wheat variety Zoria Ukrainy.

Reciprocal crosses were performed between high-yielding, regionally adapted soft winter wheat varieties (Kryzhynka, Favorytka, Podolianka, Panna, Kharus, Farandol) with winter spelt wheat (varieties Zorya Ukrainy and Europa). In the $F_{2–5}$ generations, splitting was recorded according to a number of characteristics, in particular, by spike morphology. In the fifth generation (F_5), when the progeny showed stabilization across all traits and no further splitting was observed, taking into account the general plant habit and spike morphology, all created materials were divided into soft wheat types (a medium-dense spike with normal ear scales and loose grain threshing), spelt wheat types (a long, lax spike with coarse ear scales and difficult grain threshing) and spelt-like forms (an elongated, lax or medium-dense spike with improved grain threshing quality). The selection of samples for research was carried out directly among spelt and spelt-like forms. Based on the analysis of the developed progeny and repeated selections according to productivity traits, a genetic collection of initial material was established, comprising over 200 winter spelt wheat samples differing in morphological, varietal, and economically valuable indicators. Among them, 19 best samples were selected and used as the object of research during 2019–2024. Their brief characteristics are given in Table 1.

The soil of the experimental field is podzolized heavy loamy chernozem. The content of humus in the arable layer was 3.2−3.4%, the level of saturation of the bases in the range of 90−93%, the reaction of the soil solution was medium acid (pHKCl 5.7), hydrolytic acidity was 1.9−2.3 smmol kg^{-1} of soil, the content of mobile compounds of phosphorus and potassium - 125–150 mg kg^{-1}.

All phenological observations, analysis of yield structure indicators was carried out according to the methodology for qualification testing of cereal, groat, and legume crop varieties for suitability for distribution in Ukraine (2016). Grouping of wheat samples by plant height was carried out according to the modified scale of A.P. Orliuk and co-authors (2006). Biometric indicators (plant height, number of grains per spike, length, density and weight of grain per spike) were determined on 50 plants selected in two non-adjacent replications. Quality indicators (protein, gluten, starch content, alveograph indicator, sedimentation, grain hardness) were determined by the infrared spectroscopy method using the Infratec™ Nova device (FOSS Analytical, Sweden), vitreousness - using a diaphanoscope.

The samples were ranked by alveograph indicator (a.u.) on the following scale: > 500 a.u. - excellent improver, 400–500 a.u. - good improver, 280–400 a.u. - satisfactory improver, 260–280 a.u. - valuable wheat, 240–260 a.u. – good filler, 180–240 a.u. - satisfactory filler, < 180 a.u. -weak wheat. According to the grain hardness, the wheat samples were divided into three categories: > 60 instrument units (i. u.) – hard grain type, 54–60 i. u. -medium-hard grain type, < 54 i. u. -soft grain type.

After all the calculations and analyses, the grain was threshed and the yield was determined. The threshing quality was determined by the proportion of completely threshed grain to the total amount of grain, in percent. The reliability of research, correlation-regression analysis and the significance of differences between indicators were determined at the level of significance $P < 0.05$ using Statistica 12 program (StatSoft, USA).

Table 1. Origin and description of the studied genotypes of winter spelt wheat

Sample	Parental forms ♀	♂	Description
13	Panna	Zoria Ukrainy	Short-growing (*h** = 100 cm), with an awnless, long (over 15 cm), loose white spike with coarse spike scales.
40	Panna		Medium-growing (*h* = 113 cm), with an awnless, long, lax, red spike, with tough glumes and poor threshing quality.
66	Panna		Short-growing (*h* = 95 cm), with strong straw and high lodging resistance. The spike is awned, long, loose, white in color, with coarse spike scales and poor threshing quality.
76	Kryzhynka		Medium-growing (*h* = 110 cm), awned genotype. Spike scales are softened, and the spike stem is strong, which contributes to improved grain threshability.
86	Panna		Tall-growing (*h* = 122 cm) genotype with an awnless, elongated spike (about 13 cm) of low density. It shows improved grain threshability.
95	Podolianka		Tall-growing (*h* = 120 cm) awned specimen with spiny speltoid spike of low density. Has improved grain threshing quality.
128	Zoria Ukrainy	Panna	Tall-growing (*h* = 125 cm) genotype with an awnless spike of typical spelt morphology.
155	Panna	Zoria Ukrainy	Medium-growing (*h* = 109 cm) specimen with awned long (over 16 cm), loose spike, has softened spike scales and improved grain threshing quality.
179	Podolianka		Short-growing (*h* = 100 cm) specimen with typical spelt spike morphology except for length (about 13 cm).
202	Zoria Ukrainy	Panna	Short-growing (*h* = 98 cm) specimen with awnless red long spike and poor threshing quality.
1559	Kryzhynka	Zoria Ukrainy	Short-growing (*h* = 87 cm), has increased individual plant productivity and improved grain threshability.
1674	Farandol		Short-growing (*h* = 89 cm), has increased individual plant productivity and improved grain threshability.
1691	Krasnodarska 99		Tall-growing (*h* = 120 cm) specimen with an awned, spelt-like spike of medium length and low density.
1695	Farandol		Tall-growing (*h* = 129 cm) specimen with a high tillering capacity and improved grain threshability.
1721	Panna		Medium-growing (*h* = 106 cm) specimen with an awned spike of typical spelt morphology.
1725	Kopylivchanka		Medium-growing (*h* = 110 cm) specimen with high tillering coefficient and improved grain threshing quality.
1755	Panna		Short-growing (*h* = 98 cm) specimen with high individual plant productivity and improved grain threshability.
1786	Favorytka		Semi-dwarf (*h* = 82 cm) specimen with long loose awnless spike of spelt type.
1817	Kharus		Semi-dwarf (*h* = 75 cm) specimen with high individual plant productivity and improved grain threshability.

Note: h – plant height.

RESULTS AND DISCUSSION

Spelt is a tall-stemmed species (h = > 110 cm). Despite the presence of strong straw, its tall-stemmed forms are prone to lodging. In order to reduce the height of plants, semi-dwarf (Kopylivchanka, Panna, Kharus) and low-stem (Favorytka, Podolianka, Kryzhynka) varieties of soft winter wheat were involved in the breeding process to create the initial material for spelt wheat, which allowed to obtain a significant range of variability in plant height and select highly productive semi-dwarf and low-stem genotypes.

Genetic variability of species of the genus *Triticum* L. in plant height is provided by more than 20 specific genes Rht_1–Rht_{20} (Grant et al, 2018; Yakymchuk, 2018). At the same time, the scientific literature does not describe the genetics of plant height control in the *T. aestivum* ssp. *spelta*. When hybridizing tall-stemmed spelt and common wheat varieties with dominant or recessive dwarfism, various types of gene interaction (complementary, epistatic, polymeric) and the formation of offspring with a wide range of variability in plant height are observed (Sichkar et al, 2016; Yakymchuk, 2018).

In the conducted studies, plant height varied over a wide range from 56 to 125 cm. According to the classification by A.P. Orlyuk and co-authors, all the developed materials were classified by plant height as follows: dwarfs (h < 60 cm), semi-dwarfs (h = 60–84 cm), short-stemmed (h = 85–104 cm), medium-stemmed (h = 105–119 cm), and tall-stemmed (h > 120 cm) forms (Table 2). From the point of view of practical selection, semi-dwarf and low-stem genotypes are valuable, since reducing the height of spelt plants is an urgent task of breeding. The semi-dwarf sample 1817 and low-stem samples 1559, 1674 and 1755 were distinguished, which are characterized by a high grain weight per main spike (2.24–2.48 g) and yield (5.25–5.82 t ha^{-1}). It is worth noting the high-stem sample 1695, which was characterized by the highest yield in the experiment (6.35 t ha^{-1}) and medium- and high-stem samples 95, 155, 1691 and 1725, which significantly exceeded the standard in terms of yield (5.41–5.81 t ha^{-1}).

By hybridizing soft wheat with spelt, an urgent unresolved issue of spelt breeding was addressed – the development of forms with an optimal spike structure and enhanced grain threshability. Spelt spike is long and lax, with a brittle rachis, that, when mechanically damaged, breaks into individual segments and a coarse ear scale, which tightly covers the seed and makes it difficult to thresh grain from the ear.

The length and density of the spike of hexaploid wheat species is regulated by the genes *S/s*, which determines a long, lax spike, and *C/c*, which has a pleiotropic effect and leads to a significant shortening of the spike, spike scale, and grain (Johnson, 2008). The length of the wheat spike is also regulated by the lengthening genes *L1/l1/, L2/l2.*

When spelt, which has the genotype $SSL_1L_1L_2L_2$, is hybridized with soft wheat varieties containing the *C/c* gene and differing in the allelic state of the L_1/l_1/ and L_2/l_2 genes, the resulting progeny occupies an intermediate position between the original forms or approach spelt in terms of ear length and density. This explains the elongation of the spike in the resulting progeny to 13.2–17.0 cm, which exceeds the original varieties of soft winter wheat by 1.8–2.5 cm. The spike density in all studied samples remains low (< 16.0 pcs. spikelets 10 cm^{-1} of spikelet stem).

The nature of grain threshing from a wheat spike is controlled by the *Q/q* gene (Kerber & Rowland, 1974; Kato et al, 2003). The nature of the spikelet scales (coarse or optimal spikelet scales) is controlled by the dominant *Tg* allele of the *Tg/tg* gene in the homozygous state (Sood et al, 2009). To form a phenotype with free grain threshing, it is necessary to have dominant *QQ* alleles and recessive *tgtg* alleles in the genotype. This genotype is characteristic of soft wheat. The genotype of spelt wheat is qqTgTg.

Table 2. Analysis of economically valuable traits of winter spelt wheat samples, 2019–2024

Sample	Grain weight per main spike, g	Spike length, cm	Grain number per spike, pcs.	Spike density, pcs 10 cm^{-1}	Yield, t ha^{-1}	Threshing quality, %
Zoria Ukrainy (St)	1.78 [d]	16.1 [b]	45 [b]	14.4 [c]	5.12 [d]	73 [e]
Semi-dwarfs (60–84 cm)						
1786	2.05 [c]	15.6 [c]	44 [b]	15.4 [a]	5.25 [d]	84 [b]
1817	2.48 [a]	16.1 [b]	47 [a]	14.4 [c]	5.82 [b]	87 [a]
Low-growing (85–104 cm)						
13	1.45 [f]	13.7 [e]	43 [c]	15.3 [a]	3.87 [f]	81 [c]
66	1.71 [e]	14.3 [d]	41 [d]	14.5 [b]	4.31 [e]	73 [e]
179	1.42 [f]	13.2 [e]	47 [a]	15.5 [a]	4.16 [f]	77 [d]
202	1.40 [f]	18.2 [a]	41 [c]	13.6 [d]	4.30 [e]	75 [e]
1559	2.34 [a]	15.3 [c]	48 [a]	15.7 [a]	5.65 [b]	87 [b]
1674	2.06 [c]	14.6 [d]	44 [b]	15.1 [b]	5.28 [c]	86 [b]
1755	2.24 [b]	17.0 [a]	46 [a]	14.5 [b]	5.25 [c]	89 [a]
Medium-growing (105–119 cm)						
40	1.22 [g]	14.3 [d]	39 [d]	14.5 [c]	4.36 [e]	77 [d]
76	1.87 [d]	15.1 [c]	41 [c]	14.8 [b]	5.18 [d]	86 [b]
155	1.83 [d]	16.2 [b]	44 [b]	13.8 [d]	5.41 [b]	91 [a]
1721	1.54 [f]	16.2 [b]	42 [c]	13.8 [d]	4.68 [d]	78 [d]
1725	1.48 [f]	16.1 [b]	44 [b]	13.6 [d]	5.78 [b]	91 [a]
Tall-growing (> 120 cm)						
86	1.84 [d]	13.3 [e]	44 [b]	14.8 [b]	5.18 [d]	86 [b]
95	1.61 [e]	13.5 [e]	43 [b]	14.6 [c]	5.58 [b]	90 [a]
128	1.42 [f]	16.6 [b]	43 [c]	13.4 [d]	4.85 [d]	76 [d]
1691	2.02 [c]	15.6 [c]	42 [c]	14.3 [c]	5.81 [b]	82 [c]
1695	1.74 [e]	16.0 [b]	44 [b]	15.5 [a]	6.35 [a]	87 [a]

Note: different letters indicate values that are significantly different within one line according to results of the Tukey' test ($P < 0.05$).

Various variants of recombination of these genes during hybridization of soft wheat with spelt ensure the formation of hybrids with different grain threshing characteristics: from free to complicated with the formation of intermediate forms with improved grain threshing. In the conducted studies, 17 samples significantly exceeded the standard for grain threshing quality. Samples 86, 95, 155, 1559, 1674, 1695, 1725, 1755, 1786, and 1817 showed superior performance for this trait, demonstrating improved grain threshability (84–91%).

The value of spelt for breeding and production is in its high quality characteristics and technological properties of grain. When hybridizing it with other wheat types, it is important to select parental pairs in such a way that there are no significant differences in quality indicators, in particular, the content of protein and gluten in the grain, since these indicators are inherited from the worst of the parents. In the studies conducted, most samples were significantly inferior to spelt in the content of protein and gluten in the grain. However, mid-stem samples 40 and 76 were isolated, which significantly exceeded the standard in terms of protein (25.6–27.8%) and gluten (53.2–57.2%) content (Table 3).

Table 3. Technological properties of the grain of winter spelt wheat samples, 2019–2024

Sample	Content, %			Alveograph indicator, a u.	Grain hardness, i. u.	Sedimentation, mm	Vitreousness, %
	protein	gluten	starch				
Zoria Ukrainy (St)	24.2 ^{b}	52.1 ^{a}	50.8 ^{d}	320 ^{d}	62.2 ^{b}	64.7 ^{a}	88 ^{a}
Semi-dwarfs (60–84 cm)							
1786	19.7 ^{d}	41.6 ^{d}	53.4 ^{c}	285 ^{e}	58.1 ^{c}	62.2 ^{c}	83 ^{b}
1817	20.9 ^{c}	43.5 ^{d}	52.8 ^{c}	340 ^{c}	60.7 ^{b}	63.1 ^{b}	86 ^{a}
Low-growing (85–104 cm)							
13	24.5 ^{b}	51.8 ^{b}	50.2 ^{e}	345 ^{a}	65.5 ^{a}	65.2 ^{a}	88 ^{a}
66	19.7 ^{d}	39.9 ^{e}	53.2 ^{b}	280 ^{e}	57.7 ^{c}	63.5 ^{b}	87 ^{a}
179	21.5 ^{c}	44.5 ^{d}	51.2 ^{d}	295 ^{d}	61.2 ^{b}	65.4 ^{a}	85 ^{b}
202	21.9 ^{c}	43.2 ^{d}	51.0 ^{d}	340 ^{c}	59.5 ^{c}	63.7 ^{b}	87 ^{a}
1559	20.9 ^{c}	42.8 ^{d}	51.8 ^{d}	325 ^{c}	61.7 ^{b}	58.8 ^{d}	81 ^{c}
1674	16.8 ^{g}	35.1 ^{f}	58.1 ^{a}	300 ^{d}	53.2 ^{e}	59.2 ^{d}	68 ^{f}
1755	17.8 ^{e}	37.3 ^{e}	55.6 ^{b}	325 ^{c}	56.8 ^{d}	64.1 ^{a}	76 ^{d}
Medium-growing (105–119 cm)							
40	28.7 ^{a}	57.2 ^{a}	50.0 ^{e}	425 ^{a}	65.4 ^{a}	68.2 ^{a}	90 ^{a}
76	25.6 ^{a}	53.2 ^{a}	50.7 ^{e}	385 ^{b}	64.8 ^{a}	62.2 ^{c}	88 ^{a}
155	17.8 ^{f}	37.5 ^{e}	55.4 ^{c}	375 ^{b}	57.6 ^{c}	60.1 ^{c}	80 ^{c}
1721	21.4 ^{c}	45.4 ^{c}	52.7 ^{c}	355 ^{b}	59.1 ^{c}	60.8 ^{c}	85 ^{b}
1725	16.8 ^{e}	36.3 ^{f}	56.7 ^{b}	250 ^{f}	57.7 ^{c}	51.1 ^{e}	72 ^{e}
Tall-growing (> 120 cm)							
86	19.2 ^{d}	42.4 ^{d}	52.3 ^{c}	295 ^{d}	58.8 ^{c}	61.6 ^{c}	87 ^{a}
95	17.8 ^{f}	36.3 ^{f}	56.3 ^{b}	295 ^{d}	57.6 ^{c}	60.5 ^{c}	81 ^{c}
128	23.8 ^{b}	49.1 ^{b}	51.2 ^{d}	340 ^{c}	61.3 ^{b}	60.8 ^{c}	80 ^{c}
1691	21.7 ^{c}	44.5 ^{d}	51.8 ^{d}	325 ^{c}	61.7 ^{v}	63.4 ^{b}	82 ^{c}
1695	18.8 ^{e}	41.0 ^{e}	54.4 ^{c}	325 ^{c}	57.5 ^{c}	58.9 ^{d}	74 ^{e}

Note: different letters indicate values that are significantly different within one line according to results of the Tukey' test ($P < 0.05$).

Flour strength is the main determining element of its baking properties. The greatest influence on this indicator is the amount and quality of gluten, the state of the protein-proteinase complex, the activity of proteolytic enzymes, the presence of activators and inhibitors of proteolysis, etc. The studies have shown that the alveograph indicator varied depending on the genotype within the range from 285 to 425 a.u. It was the highest in samples 40 (425 a.u.), 76 (385 a.u.) and 155 (375 a.u.). According to the classification by alveograph indicator, sample 40 was identified as a good improver, sample 1725 - as a good filler, and the other studied genotypes were identified as satisfactory improvers.

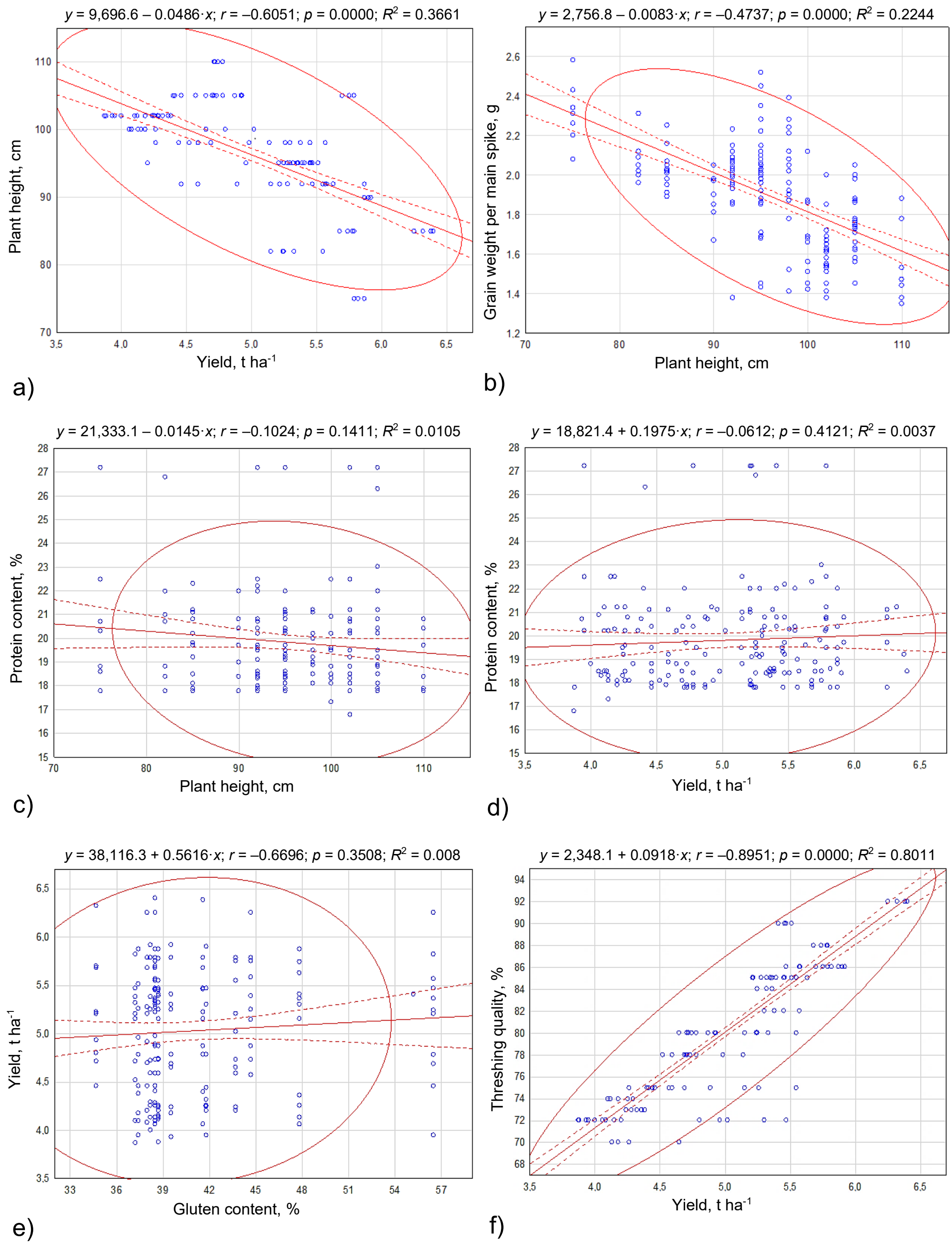

Figure 1. Dot plots and the theoretical lines of regression of the relationships according to the linear correlation between the plant height and grain weight per main spike of spelt wheat (a); plant height and yield of spelt wheat (b); protein content and plant height of spelt wheat (c); protein content and yield of spelt wheat (d); gluten content and yield of spelt wheat (e); threshing quality and yield of spelt wheat (f).

The characteristic 'hard grain/soft grain' is used for technological specialization of wheat varieties. Hard-grained genotypes are optimally suitable for the bread and bakery product production. Soft-grained genotypes are often called biscuit and are used in the confectionery industry. Among the created materials, samples 13, 40, 76, 128, 179, 1559, 1691, 1817 were identified as hard-grained, sample 1674 - as soft-grained, and the rest - as semi-soft grained.

Scientists point out that with a decrease in plant height, the morphological and anatomical features of spelt change, which significantly affects the development of other traits (Zečević et al, 2005; Kochmarskyi, 2012). The conducted correlation-regression analysis indicates a negative correlation of medium strength between yield and height of spelt wheat plants (Fig. 1, a) $r = -0.60 \pm 0.00$; $y = 6{,}696.1 - 0.0486 \cdot x$, where x is plant height (cm), y – is yield, (t ha^{-1}).

A negative correlation of medium strength was observed between grain weight per spike and plant height (Fig. 1, b): $r = -0.47 \pm 0.00$; $y = 2{,}756.8 - 0.0083 \cdot x$, where x is plant height (cm), y – is grain weight per spike (g). A weak negative correlation was found between plant height and protein content (Fig. 1, c): $r = -0.10 \pm 0.14$; $y = 21{,}333.1 - 0.0145 \cdot x$, where x is protein content (%), and y – is plant height (cm). A weak correlation was observed between yield and protein content in the grain (Fig. 1, d): $r = 0.06 \pm 0.41$; $y = 18{,}821.4 + 0.1975 * x$, where x is yield (t ha^{-1}), and y – is protein content (%). It was found that spelt wheat yield is significantly influenced by threshing quality (Fig. 1, f): $r = 0.89 \pm 0.00$; $y = -2{,}348.1 + 0.0918 \cdot x$, where x is threshing quality (%), and y – is yield (t ha^{-1}).

Conclusions

1. By hybridizing soft winter wheat and winter spelt, a new starting material of winter spelt wheat was created, which is characterized by a high level of manifestation of economic-valuable characters and can be used in breeding schemes for creating high-yielding crop varieties.

2. Spelt wheat samples were identified that can be used in practical breeding as donors of genes for individual traits, in particular, high-yielding (yield 5.25–5.82 t ha^{-1}) semi-dwarf and low-stem samples 1786, 1817, 1559, 1674 and 1755 - in breeding to reduce plant height; samples 95, 155, 1725 with improved grain threshing (90–91%) - to create forms with optimal ear structure; samples 13, 40 and 128 with a high protein content in the grain (23.8–28.7 %), gluten (49.1–57.2%) - in breeding for grain quality.

3. Consistently high yielding samples of spelt wheat 1559 and 1691 were distinguished, which successfully combine high yield (5.65–5.81 t ha^{-1}) with high grain quality (protein content - 20.9–21.7 %, gluten - 42.8–44.5%).

4. It was established that the yield of spelt wheat is significantly affected by the threshing quality ($r = 0.89 \pm 0.00$) and weight of 1,000 grains ($r = 0.72 \pm 0.00$). No strong relationship was found between yield and grain protein and gluten content. This makes it possible to conduct selective and genetic improvement of spelt simultaneously for yield and grain quality without reducing the level of mutually exclusive indicators.

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