UDC 633.16:631.527

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THE ROLE OF PRIMARY ROOT SYSTEM IN THE YIELD FORMATION OF MEDIUM TALL AND SEMI-DWARF VARIETIES OF SPRING BARLEY

In resistance to a soil drought in the early stages of seed germination the key role plays the primary root system: the number of seminal roots and their length, the length and the dry matter weight of the coleoptile. The stages and methods of development of six-row medium tall spring barley varieties Vakula and Helios, and semi-dwarf varieties Ros' and Halychanin have been described.

Key words: *spring barley, seminal roots, coleoptile, semidwarfism, variety, yielding capacity.*

Introduction. In the beginning of the last century in rural farms of the south of Ukraine over 50 % of barley grown area was occupied by multiple-row population varieties. The first breeding variety Pallidum 32 (originators: A. A. Sapegin and D. I. Baranskiy) wasdeveloped at the Ukrainian Plant Breeding and Genetics Institute in 1931 by a repeated selection of the best genotypes from a local population variety, and it was six row variety. In 1940 the variety grown area was over 700000 hectares [1].

In the early thirties of the last century Prokofiy Fomich Garkavyi begun his research activity in Odessa at the Ukrainian Plant Breeding and Genetics Institute. He was the pupil of two outstanding scientists of the last century — Andrey Afanasievich Sapegin and Nikolay Ivanovich Vavilov. The stage of scientific plant breeding has begun. For the first time in Ukraine the method of hybridization with the use of ecologically distant genotypes was used. Various two row spring barley varieties and six row winter varieties intended for fodder, food and brewing use for the steppe and forest-steppe region were developed.

The barley varieties developed by «the barley father of Soviet Union» P. F. Garkavyi over almost the time of half a century gradually occupied the major barley grown areas in Ukraine. Those varieties were also widely grown over the borders of our country: in Moldova, in the North Caucasus, in the Volga region, in the Ural Mountains region, in Kazakhstan, Kyrgyzstan, in the Far East. Over that period of time the yield capacity of barley varieties was more than doubled [1].

After the Second World War the spring barley varieties in Ukraine and almost in all the regions of the former Soviet Union were two row (99,9 %), and winter varieties — six row [2].

In the early eighties of the last century at the Laboratory of Spring Barley Intensive Varieties Breeding of the All-Union Plant Breeding and Genetics Institute a number of six-row spring barley varieties of «a new type» [1,2]: Pallidum 90, Pallidum 76 and Muromets were developed and entered the State trials. The *originators of the varieties* believed that if a six-row ear was «fasten» to the modern two-row *varieties* of barley the problem of productivity would be solved. But it did not happen. Those *varieties* under favorable soil water availability conditions exceeded in yield the two-row *varieties by* 10–20 %, but under drought conditions their yield was almost three times lower than that of the two-row *varieties*. They almost did not tiller, had wide leaves, a small and unsmooth grain, rough awns which could not be separated from the grain during thrashing. In addition, they were affected by smut and other diseases. Soon, all those *varieties* were excluded from the State trials.

It is known that the root system plays the key role inresistance to a soil drought in the early stages of seed germination. Spring barley generates more seminalroots than winter barley. The seed of two-row varieties of a steppe ecology type in the course of germination generates a considerably higher number of seminalroots, the roots of the varieties function during all the vegetation, penetrate into soil up to 125 cm and form the nodal root system earlier than varieties of a forest-steppe ecology type [3–6].

The role of seminal roots in grain productivity of spring barley in due time was thoroughly studied by Prof. A. Ya. Trofimovskaya (VIR), Prof. P. V. Danil'chuk (PBGI), PhD (Agricultural Sciences) I. F. Loshak (Kazakhstan) [5–8].

The genotypes of two-row barley varieties of a steppe ecology type generate a more developed coleoptile than six-row barley varieties. Two-row barley varieties of Irano-Turkestani group with a developed coleoptile (7–9 cm and more) less reduce field germination under *adverse growing conditions* than six-row barley varieties having short coleoptiles (4–5 cm) [7].

Over the last 50 years the geneticists and breeders of the leading breeding centers of the world have achieved considerable success in barley breeding. For this period of time in many countries the yield capacity of barley increased by more than twice. It became possible due to stage-by-stage considerable plant height reduction (60–70 cm against 90–120 cm), resistance to lodging, resistance to diseases, and an increase in number of productive tillers and grain number in an ear. The modern European varieties are capable of producing *yields* at the level of 7.5–8.0 t/ha and more when intensive farming technologies with seeding rate of 2.0–2.2 million seeds/ha are used.

The majority of the Ukrainian spring barley varieties are still insufficiently resistant to lodging. In the Forest-Steppe and Polesie regions the varieties are higher (120–150 cm) than the West European varieties, therefore they cannot be grown using intensive farming technologies. However, the Ukrainian variet-

ies of a steppe ecology type generate a more developed root system and are more tolerant to heat.

The recessive semi-dwarf gene (sdw) was located on the chromosome 3HL, and the root system as a quantitative trait is a complex index. Therefore, we believe that development of semi-dwarf genotypes, even six-row barley, with plant height no more than 60 cm is a quite real task.

In the late seventies of the 20th century an outstanding Czech breeder F. Minarzhik has developed a dwarf genotype of spring two-row barley **He-2468** of 50 cm high with two dwarf genes. The dwarf genotype formed a long (26–28 grains), loose (unlike the Japanese dwarfs with a dense ear of var. *nanum* type), an upright ear, narrow leaves with vertical orientation. Due to the increased number of tillers the genotype generated 1200–1300 culms/m^2 (a personal communication, the *Hrubšice* Breeding Station, Czechoslovakia, 1979).

Material and methods. For improvement of spring six-row barley with negative traits the two-row heat resistant genotypes of a steppe ecology type developed at our institute which possessed resistance to smut, powdery mildew and other diseases were involved in hybridization. As a female component the breeding lines obtained from crosses [(c. i.13664 x Donetskiy 4) x Odesskiy 36] x Odesskiy 36 — Medicum 32/76, Medicum 20/76, Medicum 42/76 were used. Later (1983–1987), the latter were registered for growing in many regions of the USSR under the names **Pervenets** and **Vestnik**.

The breeding work began in 1976 and continued over 30 years. In crosses two-row and six-row genotypes were involved — donors of valuable traits; composite crosses, step-by-step crosses and selections of desirable genotypes were carried out.

The varieties of two-row and six-row barley were studied by the following traits: a number of seminal roots, their length and dry matter weight, coleoptile length. 100 plants of each variety were studied. The seeds were soaked in rolls and kept in the thermostat at the temperature of 10 ˚C during 10 days in darkness. The coleoptile ruptures just in ten days, and its length remains invariable. The results of this study are presented in the table and in the figures 1, 2, 3.

Gradually we managed to develop the genotypes of six-row spring barley which did not so essentially reduce the yield under the adverse growing conditions. The developed varieties (in the co-authorship) **Vakula** (Medicum 32/76 x Pallidum 129 x Athos x Pallidum 76) and **Helios** (Medicum 32/76 x Pallidum 129 x Athos) meant for *fodder* production form a large, quite smooth grain with a thin hull; they have almost smooth awns and are more resistant to the most prevailing diseases, but they are still insufficiently resistant to lodging and ear fragility.

From the cross (Odesskiy 82 x Donetskiy 6) xHe-2468 the first in Ukraine semi-dwarf two-row barley variety **Ros'** has been developed for the Forest-Steppe and Polesie regions. In 1991 at the Nemirov variety testing station of Vinnitsa region the variety yielded 9.67 t/ha (a record in Ukraine). The

variety was enrolled in the Register of Plant Varieties in 1993. In 2000 the grown area of the variety was already 115.3 thousand hectares. But soon **Ros'** was excluded from the Register because it was affected almost by all the diseases.

Table

Seminal roots and coleoptiles of some spring barley varieties

Variety	A number of seminal roots, units	The root length, cm	The weight of the roots, g	The coleoptile length, cm	1000-grain weight, g
Pallidum 90 (var. *pallidum*)	4,42 ± 0,14	4,76 ± 0,18	4,23	4,38 ± 0,18	48,7
Muromets (var. *pallidum*)	4,52 ± 0,16	4,82 ± 0,22	4,19	4,40 ± 0,20	48,6
Medicum 32/76 (var. *medicum*)	6,59 ± 0,20	6,86 ± 0,31	5,96	6,67 ± 0,23	49,4
Pervenets (var. *medicum*)	6,68 ± 0,19	6,80 ± 0,44	5,92	6,61 ± 0,25	49,5
Pallidum 107 (var. *pallidum*)	5,22 ± 0,21	5,02 ± 0,33	4,22	4,72 ± 0,27	48,6
Vakula (var. *pallidum*)	5,57 ± 0,29	6,42 ± 0,24	5,66	6,38 ± 0,34	49,4
Helios (var. *rikotense*)	5,52 ± 0,18	6,48 ± 0,18	5,62	6,29 ± 0,16	49,6
Ros' (var. *nutans*)	5,42 ± 0,21	6,26 ± 0,30	5,89	6,48 ± 0,18	49,7
Halychanyn (var. *pallidum*)	5,28 ± 0,26	6,54 ± 0,23	5,64	6,58 ± 0,21	48,9
$НСР_{05}$	0,60	0,67	0,61	0,78	0,35

The breeding work continued. In hybridization two-row and six-row genotypes were involved, composite crosses and selections of desirable genotypes were carried out.

The first several six-row breeding lines of a dwarf type (50–60 cm against 85–90 for conventional varieties) were obtained from the cross Pallidum 107 x Ros'. (Control nursery, 5 м^2, 1995). But under drought conditions of the south of Ukraine those lines demonstrated more considerable incomplete seed set in the ear (from 30 to 70 %) than the tall genotypes. Some more years was needed — selections of desirable genotypes by the pedigree method for the following characteristics: normal viable pollen, a number of seminal roots, resistance to root rots and others traits. In 2002 the crosses were made again: Vakula x 91–67–2 (a semi-dwarf genotype), Helios x 91–67–2, 91–67–2 x Vakula, 91–67–2 x Helios. In 2007 in the control nursery around a hundred lines of a semi-dwarf type were studied. The best of them — 02–130–01, 02–130–09, 02–131–3, 02–131–5, 02–131–10, 02–131–13 — formed a large ear resistant to fragility, had good tillering capacity, were resistant to diseases, and the most important thing was that they formed normal viable pollen, and their yield was higher than the yield of Vakula and Helios (110–126 %).

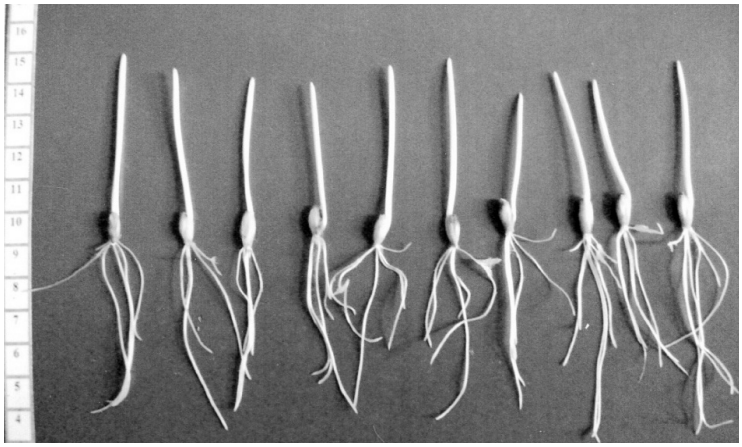

Fig. 1. Variety Muromets kept during 10 days in the thermostat at the temperature of 10°C in darkness

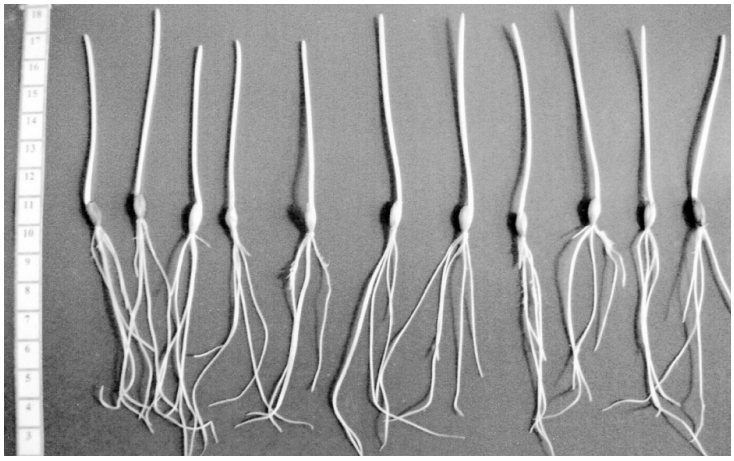

Fig. 2. Variety Pervenets kept 10 days in the thermostat at the temperature of 10°C in darkness

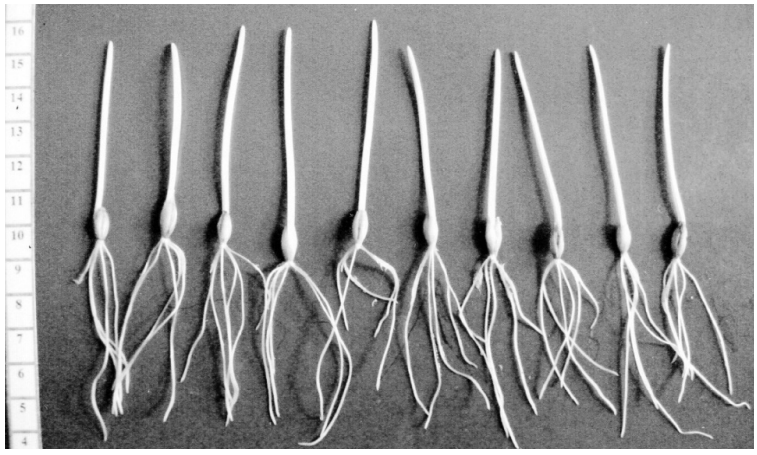

Fig. 3. Variety Halychanyn kept 10 days in the thermostat at the temperature of 10°C in darkness

In 2009 in the adaptation trial at the Khmelnitskiy Institute of I*ndustrial Agriculture* Production (Head of the Seed Production Department — V. V. Stepanchuk) when conventional farming practice was used the breeding line 02–131–5 yielded 6.83 t/ha and surpassed variety Helios by 40 % (!), and in dry year 2010 with the yield of 4.51 t/ha surpassed it by 30.2 %.

In 2010 the first in Ukraine six-row barley variety of semi-dwarf type developed for the Northern and Northwest regions of Ukraine under the name of Halychanyn was transferred to the State trials and since 2014 it will be registered in the State Register of Plants of Ukraine. In 2011–2013 in the Forest-Steppe and Polesie regions under dry conditions Halychanyn considerably surpassed in productivity other varieties. Halychanyn generates a developed root system and a developed coleoptile (table, fig. 4). It is a mid-ripening variety which has a long ear (50–70 grains) resistant to fragility, forms quite a large grain with thin hull. According to the Ukrainian Institute of Plant Varieties Examination Halychanyn is of brewing orientation. It is resistant to lodging and to the most prevailing diseases.

Fig. 4. Variety Halychanyn in dry year (PBGI, 2010)

We hope that Halychanyn growing by intensive farming technologies will find its place in the agricultural industry.

Discussion of the results. Our long-term studies of the entries of VIR barley world collection have revealed the following : by number of seminal roots the entries from Turkey, Afghanistan and Ethiopia k-6823, k-6927, k-6940, k-8946, k-8682, k-8855, k-8686, k-8692, k-8695, Jet (k-18703) significantly differ from our varieties.

The most number of seminal roots had the line SL-6823 (var. *nutans*) — 6–7 roots per plant against 4–5 in conventional varieties.

By the way, in 1985 in the entry SL-6823 the new gene **Un12** of complex resistance to smut was identified [10]. With the involvement of SL-6823 the

varieties **Prestyzh** (1995), **Het'man** (2001), **Khadgibey** (2004, Russia), **Komandor** (2007),**Sviatohor** (2010), **Voevoda** (2012) were developed.

Unfortunately, in Ukraine almost nobody is engaged in the studies on the role of seminal roots and coleoptile length in barley breeding.

The authors express their gratitude to the research workers, engineers and laboratory assistants of the institute who assisted in carrying out this work: Petkova O. S, Garkavyi O. P, Perekhrest V. A, Kholodovskaya O. M, Feoktistov P. A, Pomond S. A. and others.

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Article received 07.12 2013.

УДК 633.16:631.527

Кірдогло Є. К., Поліщук С. С. Збірник наукових праць СП–НЦНС. 2013. Вип. 22 (62).

РОЛЬ ПЕРВИННОЇ КОРЕНЕВОЇ СИСТЕМИ У ФОРМУВАННІ УРОЖАЮ СЕРЕДНЬОРОСЛИХ І НАПІВКАРЛИКОВИХ СОРТІВ ЯРОГО ЯЧМЕНЮ

У стійкості до ґрунтової посухи на ранніх етапах проростання зерна ключову роль відіграє первинна коренева система: кількість зародкових корінців, їхня довжина, маса сухої речовини корінців, а також довжина колеоптиля. Описані етапи і методи створення середньорослих сортів шестирядного ячменю Вакула і Геліос та напівкарликових Рось і Галичанин.

Таблиця — 1. Рисунки — 4. Бібліографія — 10.

УДК 633.16:631.527

Кирдогло Е. К., Полищук С. С. Сборник научных трудов СГІ–НЦНС. 2013. Вып. 22 (62).

РОЛЬ ПЕРВИЧНОЙ КОРНЕВОЙ СИСТЕМЫ В ФОРМИРОВАНИИ УРОЖАЯ СРЕДНЕРОСЛЫХ И ПОЛУКАРЛИКОВЫХ СОРТОВ ЯРОВОГО ЯЧМЕНЯ

В устойчивости к почвенной засухе на ранних этапах прорастания зерна ключевую роль играет первичная корневая система: количество зародышевых корешков, длина, масса сухого вещества и длина колеоптиля. Описаны этапы и методы создания среднерослых сортов шестирядного ячменя Вакула и Гелиос и полукарликовых сортов Рось и Галичанин.

Таблица — 1. Рисунки — 4. Библиография — 10.