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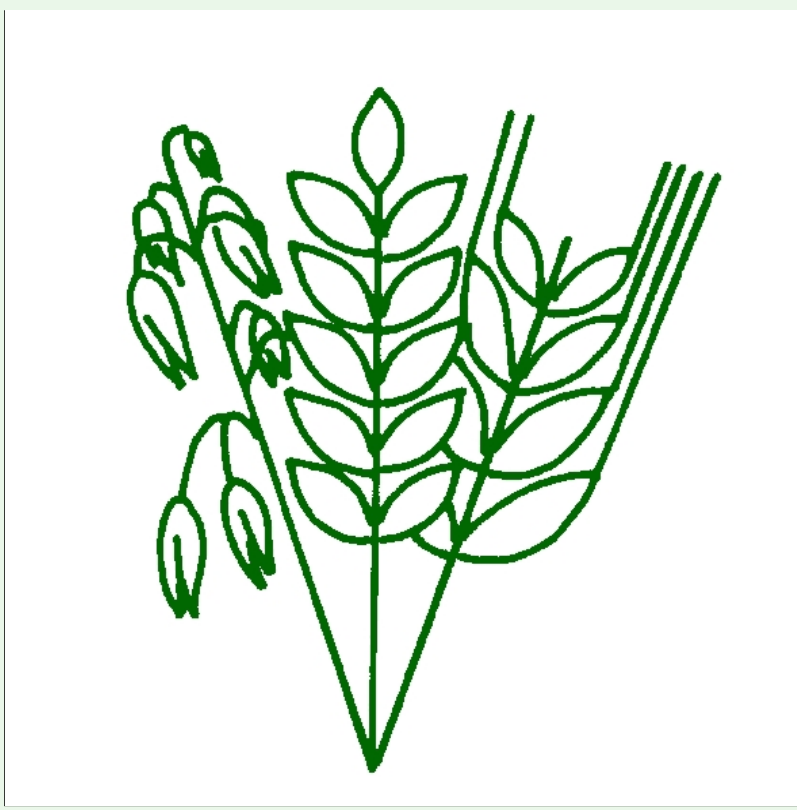
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Gene Resources of Wheat (*Triticum aestivum* L.) With Different Arrangement of Spikelets in Spike



Martinek P.¹⁾, Watanabe N.²⁾, Peng Z.-S.³⁾

¹⁾Agrotest, Agricultural Testing, Advisory Services and Research, Ltd., Havlíčkova 2787, 767 01 Kroměříž, Czech Republic, martinek@vukrom.cz;

²⁾Faculty of Applied Biological Sciences, Gifu University 1-1 Yanagido, Gifu 501-1193 Japan, watnb@cc.gifu-u.ac.jp;

³⁾China West Normal University, Nanchong, Sichuan, 637002, China, pzs8833@163.com

Based on the number of spikelets arising from individual nodes of the spike rachis, gene resources (GR) of wheat are divided into the two main groups:

1. Normal spike structure (NS), syn. 'normal spikelets' where one spikelet arises from one node of the spike rachis [Fig. 1a - d, Fig. 2a - f]. NS can be divided into:

1.1. Standard morphotype (SM) that is common for most of grown cultivars [Fig. 1a, Fig. 2a];

1.2. Multispikelet form (MS), syn. 'gigas form', with the increased number of rachis nodes and a considerably longer spike rachis [Fig. 2b] (Dencic, 1988; Peng *et al.*, 2000);

1.3. Multifloret form (MF) with a higher number of florets in spikelets [Fig. 1b, Fig. 2c]. According to the shape of spikelets we can divide MF into:

1.3.1. Flabellum which is associated with fan-like arrangements of florets, [Fig. 1b₁] (Foltyn, 1991; 1990). Some of present high-yielding European cultivars have also flabellum shape of spikelets, for example, cv. Record from Germany [Fig. 2c].

1.3.2. Prolonged spikelet rachilla with a higher number of florets in a spikelet. These materials have been obtained from the CIMMYT (Mexico) and were developed by the hybridisation with synthetic forms of wheat [Fig. 1b₂].

1.4. Long glume (LG) [Fig. 1c, Fig. 2d]. There are some wheat forms (*T. aestivum* L.) with longer glumes and lemmas (Fig. 1c, 2b). LG are characteristic for tetraploid *T. polanicum* as well as hexaploid *T. petropavlovskiy* Udacz. et Migusch (Watanabe *et al.*, 1996, 1998; Wang *et al.*, 2002). In *T. polanicum*, LG are controlled by the *P₃* gene (chromosome 7AL) and in *Triticum petropavlovskiy* by the *P₃* gene (7BL) (Watanabe & Imamura, 2002). LG were transferred to *T. aestivum* by wide hybridisation with these species. There is also information available on the near-isogenic line ANK 30 with LG which is derived from spring wheat cv. Novosibirskaya 67 (Koval, 1999; Watanabe *et al.*, 2003).

1.5. Hulled form (speltoid form) is typical for hexaploid *T. spelta* L. and *T. macha* Dekapr et Menabde. Hulled grain is determined by the *q* gene on chromosome 5AL (Cao *et al.*, 1997). In our collection there are hulled forms with short stem which were derived from hybridisation of *T. aestivum* with *T. spelta* [Fig. 2e] and *T. macha*.

1.6. Sham ramification (SR) is characteristic of the lengthening of the spikelet axis (rachilla) [Fig. 1d, Fig. 2f]. SR is also named in the literature as 'branching type *vavilovii*' that is typical for hulled *T. vavilovii* (Tum.) Jakubz. (2n = 6x = 42) [Fig. 5b]. SR was also found in tetraploid naked wheat *T. jakubzineri* Udacz. et Schachm. (2n = 4x = 28) [Fig. 5a]. The longer rachilla expression has been found also in a lot of materials developed by hybridisation of *T. aestivum* with synthetic wheats [Fig. 1d₂]. The differences between sham ramification and genuine branching can be seen in Figures 4 and 5.

2. Supernumerary spikelets (SS) are characteristic of abnormal spike morphology expressing extra spikelets per spike where more spikelets arise from one node of the spike rachis [Fig. 1e - h, Fig. 2g - j] (Peng *et al.*, 1988a; Pennell, Halloran, 1983; Huang, Yen, 1988). We can divide this group as follows:

2.1. Vertical spikelets (VS), syn. 'banana twin spikelets' and '*duospiculum*', when two spikelets arise vertically in a spike rachis node [Fig. 1e, Fig. 2g]. The VS expression is controlled dominantly or recessively. In some years, we can also find VS as non-genetic modification (Foltyn, 1989; 1995).

2.2. Horizontal spikelets (HS), syn. '*trastichon* sessile spikelets', when two or rarely three spikelets are sessile close to each other in a horizontal position in a spike rachis node [Fig. 1f, Fig. 2h] (Dencic, 1988; Foltyn, 1990; Foltyn & Ihotová, 1990).

2.3. Floribunda (F) with a high number of spikelets arising in a spike rachis node closely in vertical and horizontal position (Foltyn, 1990, 1991). This morphotype is characteristic of little space among spikelets, which often hampers the development of inflorescence organs. That may result in reduced spike fertility. According to the fertility level we can divide it into:

2.3.1. Fully sterile or considerably reduced fertility of floribunda. They occur only rarely in the F₂ generation of crosses of branched and standard forms of wheat (*T. aestivum* L.).

2.3.2. Fully fertile floribunda (Foltyn, 1991). The forms with very good fertility were developed and named **Multirow Spike (MRS)** [Fig. 1g, Fig. 2i, Fig. 6] (Martinek, 1994; Martinek *et al.*, 1996). They are characteristic of a high number of fertile spikelets per spike rachis node. Some of glumes can be missing in some spikelets, i.e. a glume number does not correspond with a spikelet number. The highest number of spikelets are developed in the lower third of the spike [Fig. 1g₂]. In the central [Fig. 1g₁] and upper [Fig. 1g₃] thirds of the spike there are mostly groups with three spikelets. The distribution of spikelets in central and upper thirds of the spike is similar to that in six-row barley in this part, however, the spikelets have more florets. The terminal part of such a spike is similar to the standard spike. The MRS is a recessive trait determined probably by one or two genes on the homoeologous chromosome of group 2. MRS was transferred in *T. aestivum* from the resource Ra-1 that was provided by the VIR in Sankt Petersburg. The new MRS lines exhibit markedly increased grain number per spike and harvest index on the level of present cultivars. The line KM 823-4-01 was developed which has the yield about 90 % of currently grown cultivars [Fig. 6 right]. Another advanced lines exhibiting improved resistance to fungal pathogens are expected to be developed.

2.4. Genuine branching (GB), syn. '*turgidum* type of branching' [Fig. 1h, Fig. 2j, Fig. 5d] is called according to branched forms of *T. turgidum* L. [Fig. 5c] (Foltyn, 1991). Spike branching has been studied by many authors (Dencic, 1988; Martinek, 1994; Pennell & Halloran, 1983; Yuan *et al.*, 1995; Peng *et al.*, 1998a, b, c; Huang & Yen, 1988). The spike branching is controlled usually by two (rarely by one or more than two) *bh* genes. Several authors divide branching into: long branch (LB) and short branch (SB). In some cases, a branching level also depends on the order and a differentiation degree of apices in one plant, which can be expressed by the presence of both branching and standard spike morphotypes in a plant, so-called 'hetero-branching' (Huang & Yen, 1988).

Independently of the above groups there are:

3. Screwedness of spike rachis (SCR) [Fig. 3a]. It is a recessive mutation (Smoček, 1991).

4. Three pistils (TP) in wheat floret [Fig. 1i, Fig. 3b]. TP were described by Professor Zheng-Song Peng. Normally the wheat produces one pistil (carpel) in a floret. TP carry three carpels in a floret [Fig. 3 above] with potential to develop into kernels [Fig. 3 below]. This trait is the mutation determined by single dominant gene (Peng, 2003).

Conclusions:

•Progress in increasing yield potential (YP) is accompanied above all by increasing the harvest index (shortening stem length and increasing spike productivity) and optimising the stand structure (Frederick & Bauer, 2000). Since optimum stem length has been attained in wheat cultivars in many regions worldwide, efforts aiming at increasing YP through spike productivity can be expected.

•Yielding ability of genetic resources have not usually reached the yields produced by check cultivars due to lower tillering ability.

•A number of days to maturity showed a higher correlation with a node number per spike rachis ($r = 0.61^{**}$) than with a spikelet number per spike ($r = 0.27^*$). It suggests that it would be possible to partly limit undesired lateness by selecting forms with a high grain number in spikelets or those with an increased number of spikelets arising from common nodes of spike rachis.

•A limited number of gene resources are important for breeding, such as those which have a higher grain number per spike rachis node (i.e. multifloret forms of NS and or forms with a higher spikelet number per rachis node VS, HS, and MRS, or forms with a higher number of kernels per floret, TP). Practical importance will depend on the transfer of perspective genes into good genetic background of present cultivars.

•The investigated genetic material can be used for genetic and physiological studies. It will be good to develop near-isogenic lines for these studies.

Figure 1.

Normal spike structure [a - d]: a - SM, b - MF (b₁ - flabellum, b₂ - multifloret with prolonged spikelet rachilla), c - LG (c₁ and c₂ - different shape of spikelets), d - SR (d₁ - hulled vavilovii type, d₂ - naked type);
Supernumerary spikelets [e - h]: e - VS (side view), f - HS, g - MRS (clusters with different numbers of spikelets g₁ - basal, g₂ - middle and g₃ - upper part of spike), h - GB, i - TP (spikelet, group of three kernels from one floret, single kernels)

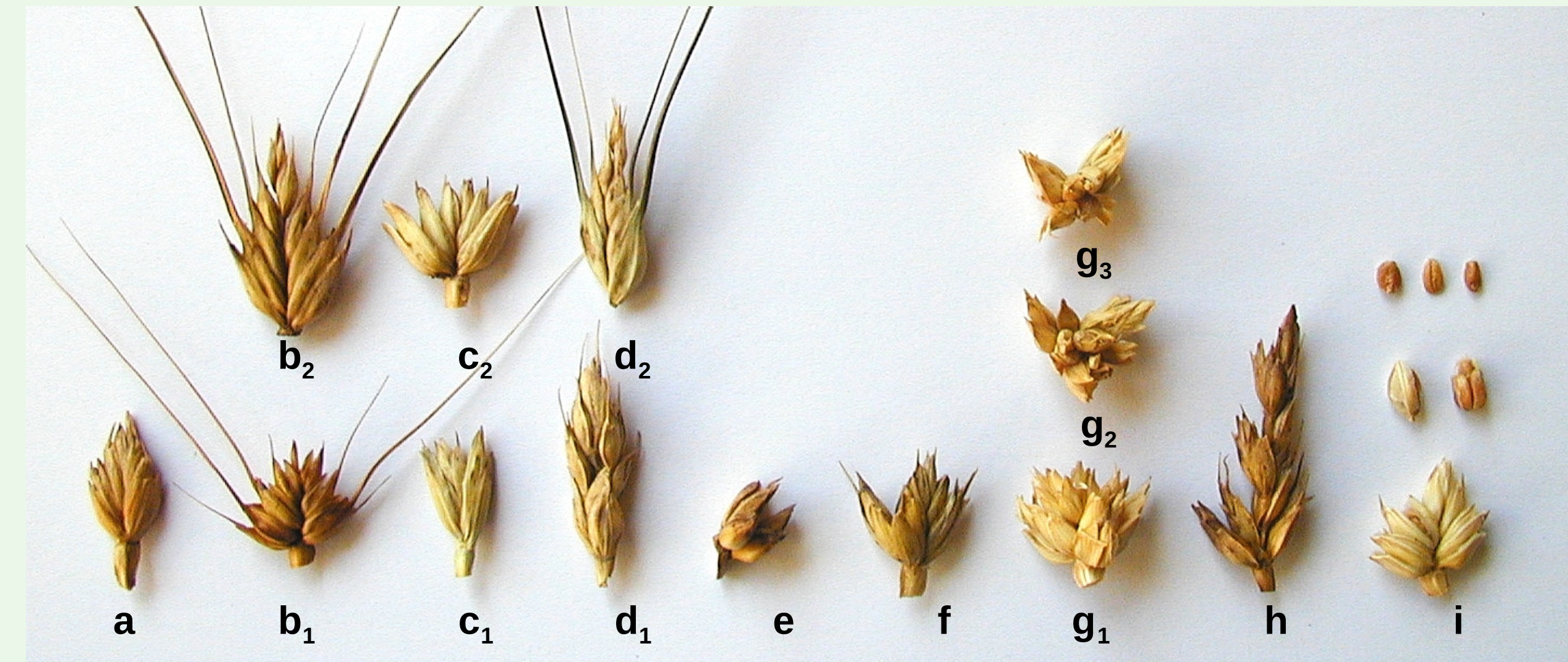


Figure 2.

Normal spike structure [a - f]: a - SM (common cultivar), b - MF (gigas), c - MF (cultivar Record from Germany), d - LG transferred from *T. polanicum*, e - HF (hulled form derived from crosses between *T. aestivum* and *T. spelta*), f - SR hulled vavilovii type;
Supernumerary spikelets [g - j]: g - VS (side view), h - HS (horizontal spikelets), i - MRS (multirow spike), j - GB (genuine branching)

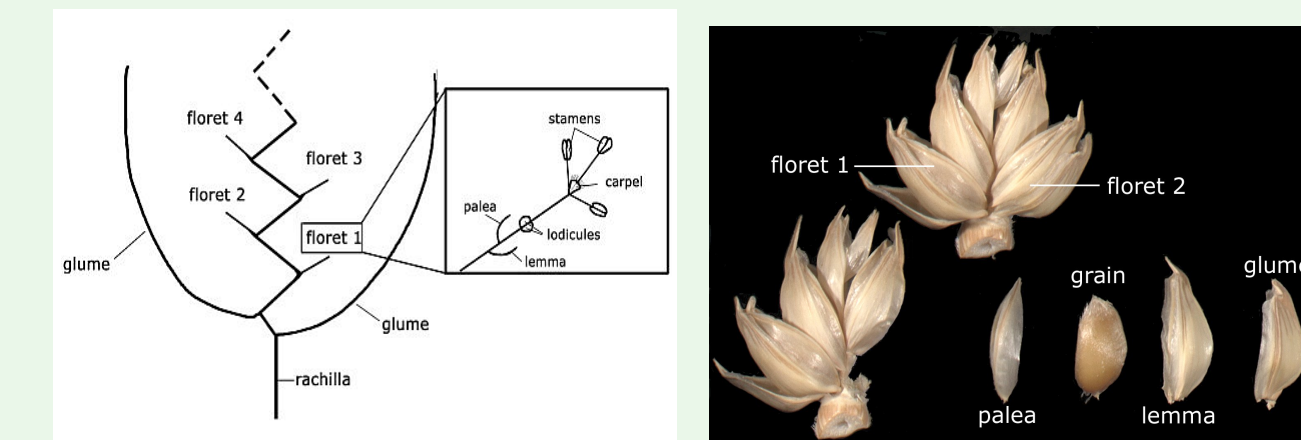


Figure 3.

a - SCR (screwedness of spike rachis);
b - TP (three pistils): wheat which is able to produce three pistils (carpels);
right above: TP wheat - floret at the flowering stage;
right below: TP wheat - floret at the maturing stage with three kernels



Figure 4.

Difference among standard morphotype (SM), sham ramification (SR) and genuine branching (GB)

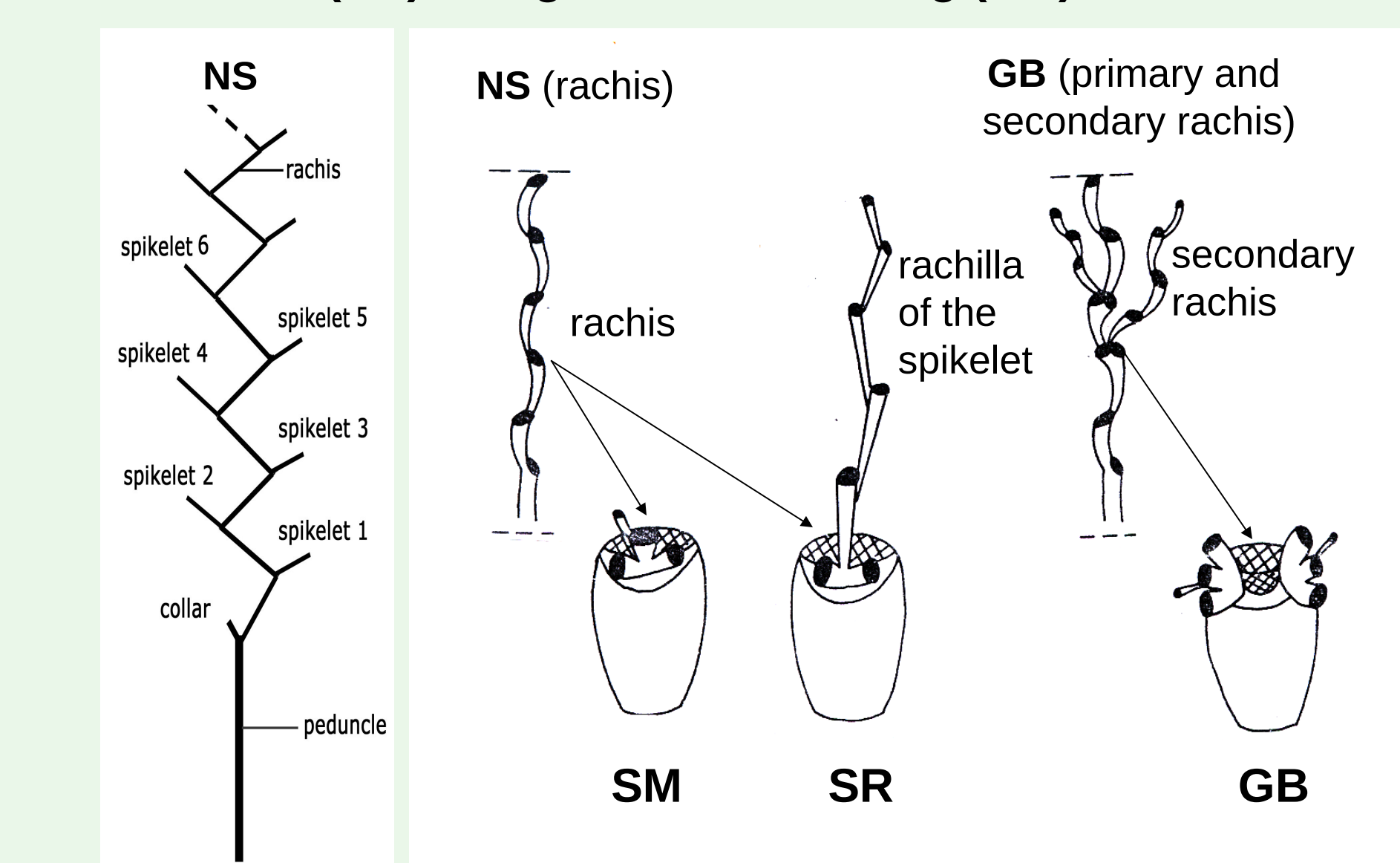


Figure 5.

Differences between sham ramification (SR) [a - b] and genuine branching (GB) [c - d]:
a - *Triticum jakubzineri* Udacz. et Schachm. var. *jakubzineri* (tetraploid naked wheat);
b - hybrid between *T. aestivum* and *T. vavilovii* (Tum.) Jakubz. (hexaploid hulled wheat - branching type *vavilovii*)
c - *T. turgidum* L. subsp. *durum* (Desf.) var. *ramosoobscurem* Jakubz. (tetraploid wheat with branched spike);
d - *Triticum aestivum* L. with branched spike transferred from *T. turgidum* L.

small pictures:
SR has the florets on the base of rachilla,
GB has the spikelets on the base of secondary rachis



Figure 6.

Multirow spike (MRS). On the left there are different spikes of MRS, in the middle - MRS with extremely high number of small kernels, on the right - the line KM 823-4-01 with relatively good yield compared with standard cultivars with standard morphotype (SM) of spike.

