Зборник Матице српске за природне науке / Jour. Nat. Sci, Matica Srpska Novi Sad, № 125, 85—91, 2013

UDC 633.16:631.6
DOI: 10.2298/ZMSPN1325087P

*Novo M. Pržulj**
Vojislava M. Momčilović

[1]Institute of Field and Vegetable Crops,
30 Maksima Gorkog Street,
21000 Novi Sad, Republic of Serbia

EFFECTS OF CULTIVAR AND YEAR ON LEAF NUMBER IN WINTER BARLEY

ABSTRACT: Leaf appearance in small cereals is the result of leaf primordium initiation and leaf primordium extension. Final leaf number (FLN) on main stem is determined by the number of primordia initiated up to the beginning of floral transition. The aim of this study was to determine the effect of growing season and cultivar on FLN in winter barley. Twelve cultivars differing in origin and time of anthesis (early, medium and late) were tested during six growing seasons (GS), from 2002/03 to 2007/08.

FLN across cultivars and GSs was 13.5. The highest FLN across GSs was in the late, six-rowed barley cultivar Kredit (14.7) and the lowest in the early, two-rowed barley cultivar Novosadski 581 (11.3). In regard to earliness, the lowest FLN was in the early groups of cultivars (12.9) and the highest in the late ones (13.9). The tested cultivars showed significant variability in FLN, which can be used for selecting most adaptable genotypes for specific growing conditions.

KEYWORDS: Barley (*Hordeum vulgare* L.), heritability, leaf number, polynomial regression

INTRODUCTION

The life cycle of cereals is divided into two main periods, period until anthesis and grain filling period. Period until anthesis can be divided into three phases: leaf initiation (vegetative phase), spikelet initiation (early reproductive phase) and spike growth (late reproductive phase) (Slafer and Whitechurch, 2001). Leaf appearance in small cereals is the result of leaf primordium initiation and leaf primordium extension. In normal growing conditions, both processes are mainly controlled by temperature (McMaster, 2005). The final number of initiated leaf primordia is proportional to the time from sowing to double ridge (Robertson et al., 1996). At the time of seed-

* Corresponding author E-mail: novo.przulj@ifvcns.ns.ac.rs

ling emergence, the shoot apex has five to seven leaf primordia and this is considered to be the range in minimum final leaf number per wheat plant (Robertson et al., 1996).

Final leaf number (FLN) is determined by the number of primordia initiated up to the beginning of floral transition. Kirby (1992) showed that sowing date and location have an effect on the variability of the number of leaves produced by winter wheat. That variation can be explained, in part, by differences in exposure to low temperature during the phase when leaf primordia are being initiated. FLN depends upon the rate and duration of leaf initiation. The vernalization response is important for fitting the plant life cycle to the environment in which it is grown, so that it can make the best use of the seasonal opportunities for growth and avoid adverse climatic factors. The major effect of vernalization is to shorten the duration of the phase of leaf primordia production (Griffiths et al., 1985). Air temperature is the main factor affecting leaf number and phyllochron (Rickman and Klepper, 1991).

Researchers have concentrated on understanding how environmental factors, first of all temperature and photoperiod and then water and nutrition, affect the FLN. Only a few studies have evaluated cultivar effect on the FLN. In this research, we studied the effect of cultivar and year on FLN of winter barley.

MATERIAL AND METHODS

Cultivars and crop management. Twelve barley cultivars (Kompolti-4, Skorohod, Novosadski 525, Novosadski 581, Plaisant, Gotic, Sonate, Boreale, Novator, Kredit, Monaco and Cordoba) which differed in origin, pedigree and agronomic traits were used in this study. A 6-year experiment was conducted from 2002/03 to 2007/08 growing season (GS) at the experiment field of Institute of Field and Vegetable Crops in Novi Sad (45°20'N, 15°51'E, altitude 86 m) on a Chernozem soil and under rainfed conditions. The experiment was conducted in a randomized complete block design with 3 replications each year. Planting density in all GSs was 300 viable seeds per m^2 for six-rowed barley and 350 viable seeds per m^2 for two-rowed barley.

To determine the FLN on the main stem, recording was done according to the Haun scale (Haun, 1973) on three tagged plants in each replication. FLN was determined as the number of leaves on the main stem, including the flag leaf. GDD for leaf number development was calculated as $Tn=[(T_7+T_{14}+2T_{21})]/4$, where T_7, T_{14}, and T_{21} were temperatures at 7 AM, 2 PM and 9 PM, respectively (Pržulj, 2001). Base temperature was 0° C.

Statistics. All data were subjected to the analysis of variance using Statistica 9.0 (StatSoft, Tulsa, OK, USA). Barley cultivars and GS were supposed to be fixed factors. When differences among earliness groups (early, medium early, late), duration of developmental phases and agronomic traits were tested, four cultivars from each group were considered as replication for detection of developmental phases. Broad-sense heritabilities were estimated using the variance components from ANOVA, as follows: $h^2=V_G/V_F$.

RESULTS AND DISCUSSION

Phenological development and phyllochron of small cereals result from genetics and numerous environmental factors (McMaster, 2005). In our study, FLN was controlled by cultivar, year and their interaction (Tab. 1). Year exhibited the highest contribution to FLN variation, about 74%. It means that the tested cultivars were genetically similar in leaf number. Low value of interaction showed stability of leaf number from year to year.

Tab. 1. – Mean squares of final leaf number (FLN) per main stem of winter barley

Source	Df	FLN
Cultivar	11	13.98**
Year	5	10.17**
C xY	55	0.98**
% components of variance		
Cultivar		17.20
Year		73.96
C xY		7.19
Heritability		0.93

** – significant at the 0.01 level

Considered across the GSs, the early cultivar Novosadski 581 had the lowest and the late cultivar Kredit the highest FLN (Tab. 2). In the cultivar Novosadski 581, early maturity was due to a reduction in FLN. Juskiew et al. (2003) found that, in spring barley, earliness was due to accelerated postanthesis growth rather than reduction in leaf number and phyllochron. Even though the cultivar x year effect on FLN was significant and participated in total variation with 7.2% (Tab. 1), the FLN variability due to interaction cultivar x year was rather small (Tab. 2).

Although differences in FLN were observed among the cultivars (Tab. 1, 2) they could not be ranked according to their FLN. For example, the early cultivar Kompolti-4 had one of the highest FLNs in 2002/03 GS and one of the lowest in 2005/06 GS (Tab. 2). The average FLN for the barley main stem was 13.5.

Across GSs and maturity classes, the early maturity group was the fastest in completing the FLN (Fig. 1I). The relationship between GDD requirement and FLN per main stem fitted the best the quadratic equation, with R^2>0.99. Also, quadratic equation was the most fitting for the relationship between leaf number development across cultivars in the same maturity group and GS, with R^2>0.97 (Fig. 1, II).

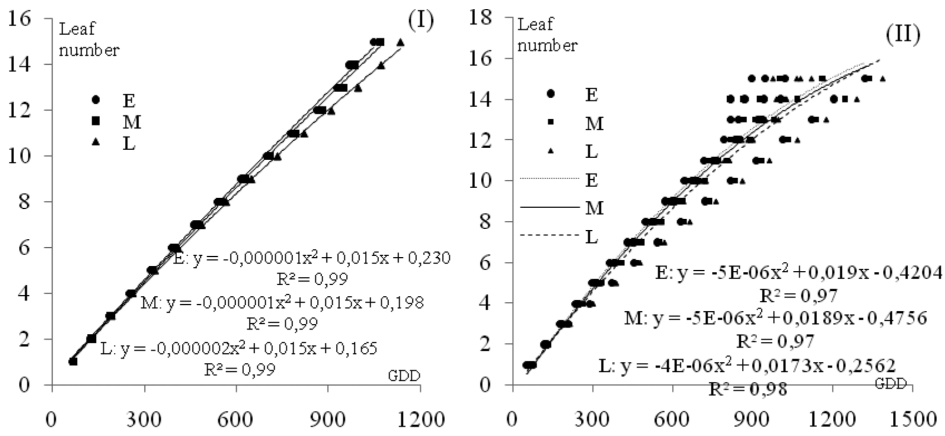

Fig. 1. – (I) Leaf number development in four early (E), four medium (M) and four late (L) winter barley cultivars across six GSs

(II) Leaf number development of three winter barley maturity classes (E-early, M-medium, L-late) in different GSs. Each point represents the average of four cultivars belonging to a maturity group in individual GS. There are six points for each leaf per maturity group

Tab. 2. – Final leaf number per main stem of twelve winter barley cultivars during six growing seasons (GS)

Cultivar	GS						
	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	Average
Kompolti-4 (E, 6R)	14	15	13	13	15	14	14.0
Skorohod (E, 6R)	13	14	12	13	14	14	13.3
Novosadski 525 (E, 2R)	13	13	12	13	13	13	12.8
Novosadski 581 (E, 2R)	10	12	10	12	12	12	11.3
Plaisant (M, 2R)	15	13	13	13	15	14	13.8
Gotic (M, 6R)	15	13	14	13	15	14	14.0
Sonate (M, 2R)	13	13	12	13	14	13	13.0
Boreale (M, 2R)	13	13	12	13	14	13	13.0
Novator (L, 2R)	15	15	13	14	15	14	14.3
Kredit (L, 2R)	15	15	14	15	15	14	14.7
Monaco (L, 6R)	13	13	13	13	14	14	13.3
Cordoba (L, 6R)	14	14	13	14	14	15	14.0
Average	13.6	13.6	12.6	13.2	14.2	13.7	13.5
LSD		Cultivar	Year	CxY	CV		
	0.05	0.17	0.12	0.42	1.9%		
	0.01	0.23	0.16	0.56			

E – early, M – medium, L – late, 2R – two-rowed, 6R – six-rowed

In our investigation, the FLN was positively correlated with GDD accumulated until flag leaf completion, while the effect of precipitation was less important (Tab. 3).

Tab. 3. Simple correlation between final leaf number (FLN) and temperature and precipitation during some barley phenological growth stages (FGS)

FGS	GDD from E till DR	Precipitation from E till DR	GDD during DR	Precipitation during DR	GDD during J	Precipitation during J
FLN	0.35**	-0.25*	0.34**	-0.27*	0.79*	-0.16

GDD – growing degree days, E – emergence, DR – double ridge, J – jointing
*, ** – significant at the 0.05 and 0.01 levels, respectively

When difference among earliness groups was tested, i.e. four cultivars from each group were considered as replication, FLN was under control of maturity classes and years (Tab. 4). The interaction maturity class x year was not statistically significant (Tab. 4), i.e., the early cultivars usually have the lowest FLN and the late ones the highest FLN (Tab. 5). Across the studied GSs, the early cultivars had 12.9, medium early 13.5, and late 13.9 main stem leaves (Tab. 5).

Tab. 4. – Mean squares of final leaf number (FLN) per main stem for three maturity classes (early, medium, late) of winter barley

Source	df	FLN
Maturity class	2	8.56**
Year	5	3.39^{**}
Maturity class x year	10	0.58^{ns}
% components of variance		
Maturity class		14.90
Year		20.82
Maturity class x year		25.91
Heritability		0.71

** – significant at the 0.01 level, ns – non significant

The identification of genetic variability of leaf area is a crucial step in plant breeding. (Royo et al., 2004). This is particularly important in species with a narrow genetic background, which may be a result of the selection pressure applied in breeding programs. Understanding of how changes in photosynthetic area may be affected by environmental conditions – particularly drought stress under field conditions – could provide a basis for developing superior high yielding varieties. Genotype by environment interactions should be taken into account to determine the optimum breeding strategy in a target environment.

Tab. 5. – Final leaf number (FLN) per main stem for three maturity classes (early, medium, late) across six GS

Maturity class	GS						Average
	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	
Early	12.5	13.5	11.8	12.8	13.5	13.2	12.9
Medium	14.0	13.5	12.7	13.0	14.5	13.5	13.5
Late	14.2	13.8	13.2	14.0	14.5	14.2	13.9
Average	13.6	13.6	12.6	13.2	14.2	13.7	13.5
		Year	Maturity cl.	Y x G	CV		
LSD	0.05	0.76	0.54	1.31	6.9%		
	0.01	1.01	0.71	1.75			

Since FLN is mainly defined by interaction between cultivar and growing conditions, the choice of appropriate cultivar for certain growing conditions is an important task for barley growers. The time of anthesis is an important physiological trait as a criterion of selection in barley breeding. Anthesis can be presented as a function of the leaf number produced by the main stem. Most of the environmental and genetic variation from seedling emergence to anthesis results from variation in the number of leaves produced by the main stem (He et al., 2011). Although variation in FLN was mainly affected by growing conditions, heritability for FLN was high in our study. Also, the early maturing cultivars had lower and late maturing cultivars had higher FLN on the main stem.

CONCLUSION

The average FLN on the main stem of winter barley grown under the conditions of the Pannonian Plain was 13.5. The early cultivars had one leaf less than the late cultivars. Although non-genetic factors were important in FLN, variation in FLN was rather a conservative trait, the early maturing cultivars having low and the late maturing cultivars high FLNs.

REFERENCES

Griffiths, F.; Lyndon, R. F.; Bennett, M. D. (1985): The effects of vernalization on the growth of the wheat shoot apex. *Annals of Botany*, 56: 501–511.

Haun, J. R. (1973): Visual quantification of wheat development. Agronomy Journal, 65: 116–119.

He, J.; Le Gouis, J.; Stratonovitchc, P.; Allard, V.; Gaju, O.; Heumez, E.; Orford, S.; Griffiths, S.; Snape, J. W.; Foulkes, M. J.; Semenov, M. A.; Martre, P. (2011): Simulation of environmental and genotypic variations of final leaf number and anthesis date for wheat. *European Journal of Agronomy*, doi:10.1016/j.eja. 2011.11.002.

Juskiw, P. E.; Helm, J. H. (2003): Barley response to seeding date in central Alberta. Can. *J. Plant Sci*., 83: 275–281.

K i r b y, E. J. M. (1992): A field study of the number of main shoot leaves in wheat in relation to vernalization and photoperiod. *Journal of Agricultural Sciences*, 118: 271–278

M c M a s t e r, G . S . (2005): Phytomers, phyllochrons, phenology and temperate cereal development. *Journal of Agricultural Science*. 43: 1–14.

P r ž u l j, N. (2001): Cultivar and year effect on grain filling of winter barley. Plant Breeding and Seed Science 45:2: 45–58.

R i c k m a n, R. W.; K l e p p e r, B. L. (1991): Tillering in wheat. In: Hodges T. (ed). *Predicting crop phenology*. Boston, CRC, pp 3–83.

R o b e r t s o n, M. J.; B r o o k i n g, I. R.; R i t c h i e, J. T. (1996): Temperature Response of Vernalization in Wheat: Modeling the Effect on the Final Number of Mainstem Leaves. *Annals of Botany*, 78: 371–381.

R o y o, C.; A p a r i c i o, N.; B l a n c o, R.; V i l l e g a s, D. (2004): Leaf and green area development of durum wheat genotypes grown under Mediterranean conditions. *European Journal of Agronomy*, 20: 419–430.

S l a f e r, G. A.; W h i t e c h u r ch, E.M. (2001): Manipulating wheat development to improve adaptation and to search for alternative opportunities to increase yield potential. In: Reynolds, M. P., Ortiz-Monasterio, J. I. and McNab, A., (Eds.) *Application of Physiology in Wheat Breeding*. pp. 160–170, CIMMYT. Mexico, DF.

УТИЦАЈ СОРТЕ И ГОДИНЕ НА БРОЈ ЛИСТОВА КОД ОЗИМОГ ЈЕЧМА

Ново М. Пржуљ, Војислава М. Момчиловић
Институт за ратарство и повртарство
Максима Горког 30
21000 Нови Сад, Србија

РЕЗИМЕ: Појава листова код стрних жита резултат је формирања и издуживања примордија листова. Коначан број листова на главном стаблу зависи од броја формираних примордија до појаве примордија класића. Циљ овога истраживања је да се одреди утицај године и сорте на коначан број листова на главном стаблу код озимог јечма. Дванаест сорти јечма, дивергентних по пореклу и времену цветања (ране, средње, касне) тестиране су у периоду од шест производних сезона. Просечан број листова на главном стаблу за испитиване сорте и сезоне износио је 13,5. Највећи просечан број листова (14,7) имала је касна сорта шесторедог јечма „Кредит“, а најмањи (11,3) рана сорта дворедог јечма „Новосадски 581“. У односу на групе зрења најмањи број листова био је код групе раних сорти (12,9), а највећи код групе касних сорти (13,9). Испитиване сорте разликовале су се значајно у коначном броју листова, што се може искористити у избору адаптабилних генотипова за одређена подручја.

КЉУЧНЕ РЕЧИ: Јечам (*Hordeum vulgare* L.), број листова, криволинијска регресија