Yield performance of two buckwheat genotypes grown as a full-season and stubble-crop

F. Bavec[1], S. Pušnik[2], I. Rajčan[3]

[1]*Faculty of Agriculture, University of Maribor, Slovenia*
[2]*Institute of Agriculture, Maribor, Slovenia*
[3]*University of Guelph, Canada*

ABSTRACT

Traditional way of growing buckwheat (*Fagopyrum esculentum* L.) in Slovenia is stubble-crop production, but grown as a full-season crop it yields more. Genotypes that are adapted to stubble-crop system may not necessarily be the best adapted for the full-season crop. The objective of this study was to determine yield performance of two buckwheat genotypes under stubble-crop and full-season production system. The experiments (randomised block design) were conducted in Podravje region with two common determinant buckwheat genotypes (land race population and cultivar Darja) in 1997 and 1998. Buckwheat grown as a full-season crop had a greater leaf area index, more flower clusters, more developed seeds and 42% higher yield than the stubble-crop buckwheat. Although cultivar Darja had 10% less flower clusters than the land race population, the number of flowers and the number of developed grains were higher. The 35% higher grain yield of cultivar Darja was associated with larger leaf area index than land race population (4.0 vs. 2.3). Cultivar Darja outperformed the land race population under full-season crop production, whereas the yield difference between the two varieties was not significant under the stubble-crop production. These results suggest that the best yielding buckwheat genotypes should be determined separately for stubble-crop and/or full-season production system.

Keywords: *Fagopyrum esculentum*; genotype; production system; leaf area index; yield

Buckwheat is becoming a popular food source outside its traditional growing areas (Aufhamer and Kübler 1998). The reasons are the high nutritional value and medical properties of buckwheat (Bavec 2000). For example, buckwheat seeds are rich in vitamins B_1, B_2 and P, digestible proteins, favourable fatty acids and minerals (Michalova 1998, Aufhammer et al. 1999). In alternative medicine, it is used for balancing the sugar and cholesterol level in the blood. The medical properties of buckwheat are associated with the high content of choline, which is known to reduce high blood pressure (Jiang et al. 1995).

Buckwheat is an important cash crop in Slovenia, yielding 1022 and 1308 kg grain.ha^{-1} for stubble and full-season crop, respectively. Because of the short life cycle (from 90 days) of buckwheat and relatively long growing (frost-free) season in Slovenia (i.e., more than 150 days), buckwheat is primarily grown as a stubble-crop (i.e., following early vegetables, barley or wheat) and seldom as a full-season crop.

In general, early spring sowing of buckwheat, leads to higher leaf area index (LAI), total biomass and grain yield, but the growth of plants can be damaged by late frost (Aufhammer et al. 1994), temperatures exceeding 17.5°C (Sugimoto and Sato 1999), or by lodging, while late sowings may suffer from lack of moisture at emergence, short assimilation period and formation of short stems. Number of flowers, flower clusters and the seed set vary with sowing date often associated with risk of water shortage (Aufhammer et al. 1994, Hagiwara et al. 1998, Liszewski 1999). Hagiwara et al. (1998) and Michiyama and Hayashi (1998) while considerable differences among genotypes in growth pattern, flowering and ripening have been reported. However, information on yielding capacity is limited and can be derived only from the conditions featuring the cultivar sown under production systems.

The major advantage of the full-season production system, however, is higher yields. Varieties that are adapted to the traditional system of growing buckwheat as a stubble crop may not be for the full-season production system. Therefore, the objective of this study was to investigate yield performance and associated morphological characteristics of two buckwheat genotypes under the full-season and stubble-crop production system.

MATERIAL AND METHODS

Site description

Field tests were conducted in 1997 and 1998 at the University of Maribor (43°34’ N Lat., 15°38’ E Long.) in sandy loam Mollisols with 2.3% organic C and pH 6.9 and 6.5 (0.1M KCl). Two common Slovene buckwheat genotypes were evaluated: cultivar Darja (introduced in 1988) and land race, i.e. land race population from Dolenjska region sown under the full-season and stubble-crop production system. In both years, the experimental design was a randomised complete block with four replications.

Individual plot size was (5 × 2 m) 10 m^2 plus a border area 0.5 m wide.

The year before, the main crop was potato fertilized with 40 $t.ha^{-1}$cattle manure, followed by conventional ploughing in October after potato harvest. In April, secondary soil cultivation was performed before sowing. Sowing dates under the full-season production system were May 17 and 20, and under the stubble crop production system July 21 and 15 in 1997 and 1998, respectively. Seed was sown at 0.12 m row distance by hand. Sowing depth was 3–4 cm. Plants were over-seeded and thinned at the stage of 2–3 leaves to a final stand of 250 $plants.m^{-2}$. Because of the high content of K (55.9 mg $K_2O.100\ g^{-1}$ soil in both years, ammonium lactat), P (33.3 and 40.7 mg $P_2O_5.100\ g^{-1}$ soil, ammonium lactat), and mineral N reserves (61 and 58 kg $N_{min}.ha^{-1}$ extracted with $CaCl_2$, in 0–0.60 m soil depth, in soil sampled on May 4 in 1997 and 1998, fertilizers were not used. The part of the field intended for stubble cropping was tilled prior to sowing. Chemical protection was not required and weeds were removed by hand. For adequate pollination, bees (*Apis melifera* L.) were placed near the field during flowering period.

Average 30-year annual rainfall in the experimental area was 999.0 mm with 766 mm in the growth period from April to October with two annual maxima in June (121.6 mm) and August (130.8 mm). In the experimental periods in June, July and August, rainfall was higher (Table 1) in both years than the 30-year average.

30-year average temperature from April to October is 9.2°C, with 58 days of temperatures over 25°C, average July temperature is 19.3°C. In entire experimental period, there were small deviations from average temperature between years, except June–August period when we noted higher monthly temperature deviations (Table 1).

Data collection and measurements

For the purpose of morphological investigation, 10 plants were sampled in the middle of the plots, 0.5 m from the border area. All individual-green leaf areas without leaf stems were measured by personal computer and scanner, which enabled counting the number of black dots on the leaves screening picture and determining the leaf area (Bavec and Bavec 2001, 2002). Leaf areas were measured at the plant stage of main stalk and 2–3 branches (i.e. July 4 and August 25 in the 1st year, July 1 and August 19 in the 2nd year, for full-season and stubble-crop, respectively). LAI was calculated as a rate between leaf and plot area. The number of opened flowers was counted in intervals of 7–10 days, as well as the number of fully formed seeds. Length of the intervals presenting one flower cycle depended on climatic conditions for all 10 plants number of developed seeds was monitored disregarding green seeds and seeds without endosperm.

Harvest time was at the stage of 75% fully matured seeds. 10 m^2 per plot inside the border areas were harvested by hand, because the losses by combine harvest can be 40–50% (Lee et al. 1996). Full-season crops were harvested from September 26–29, and stubble-crops from October 12–18 in both years. Grain yield was calculated at 13% moisture.

Data analysis

Analysis of variance (ANOVA) was performed using STATGRAPHIC©*Plus* 4.0, and significance determined at $P \leq 0.05$ (*) and 0.01 (**), respectively. The Tukey test was used to determine significant differences (at $P \leq 0.05$) between (2) years × 2 genotypes × 2 production systems (full-season and stubble). Two-tailed Pearson correlation (using SPSSX 7.5) between variables was calculated, using means across years, genotypes and production systems ($n = 32$).

RESULTS AND DISCUSSION

LAI, the main determinant of light interception, and hence photosynthetic performance reached higher values under the full-season than the stubble-crop production system, and varied with year, genotype and year × genotype interaction (Table 2). LAI also shown by the correlation between LAI and grain yield ($r = 0.49^*$) and LAI and number of developed seeds ($r = 0.56^*$), similar to Rajbhandari et al. (1995).

Then number of flower clusters significantly differed among all major factors (year, genotype, production system) and interactions except year × genotype, the num-

Table 1. Rainfall and average temperatures during the growth period in experimental circumstances

Month	1st year		2nd year	
	temperature (°C)	rainfall (mm)	temperature (°C)	rainfall (mm)
May	14.1	58.9	13.3	49.3
June	17.2	158.7	17.9	152.5
July	17.8	176.2	18.8	247.2
August	17.1	215.3	18.6	137.9
September	13.7	77.1	13.7	174.6
October	7.1	16.4	9.2	164.7

Table 2. Significance levels for LAI variables at the stage of 2–3 branches; number of flower clusters, number of flowers, developed seeds per plant and grain yield

Source of variation		LAI	No. of flower clusters	No. of flowers	No. of developed seeds	Grain yield (kg.ha^{-1})
Production system (PS)		**	**	**	*	**
Year (Y)		**	**	NS	**	**
Genotype (G)		**	*	NS	**	**
Y × PS		NS	*	**	**	**
Y × G		**	NS	NS	NS	**
PS × G		NS	**	NS	**	**
Y × PS × G		NS	**	NS	NS	*
CV (%)		54.5	33.6	31.2	59.7	30.7
Main effect treatment means						
Production system	full-season crop (FS)	4.0a	8.4a	208.5a	39.3a	1752.5a
	stubble-crop (S)	2.3b	4.9b	152.8b	18.7b	1023.7b
Year	1st	2.3b	7.1a	167.7a	25.8b	1501.2a
	2nd	4.0a	6.2b	193.6a	32.2a	1275.0b
Genotype	cultivar Darja	4.0a	6.3b	184.5a	37.8a	1678.7a
	NP	2.3b	7.0a	176.8a	20.3b	1097.5b

NP – natural population, i.e. land race population
by 1 degree of freedom
*, ** significant at the 0.05 and 0.01 probability levels, respectively
NS – not significant ($P > 0.05$)
a, b – means of separate variables with different letters are significantly different at $P \leq 0.05$

ber of flowers only among production systems and year × production system interaction. Crops under the full-season production system had higher numbers of flowers and flower clusters than under the stubble production system (Table 2).

Stubble buckwheat had a shorter period from sowing till the end of flowering growth than from buckwheat under full-season production system, but the number of flowers in all treatments increased 50–55 days after sowing and the number of formed seeds varied between 20–55 seeds per plant (data not shown). In Aufhammer et al. (1994) investigation the number of flowers increased from 60–70 days after sowing and number of seeds varied from 60 to 100 seeds per plant. According to our and Aufhammer et al. (1994) data phenological development depends on temperature sum (days °C) and day length. Our results shoved that number of flowers were significantly different only between sowing dates, i.e. production system and year × production system interaction (Table 2), contrary to Aufhammer et al. (1994), where the number of flowers varied with year, sowing date and genotype. There was a slight difference in number of flowers (data not shown) between sowing in March (Sugimoto and Sato 1999) or in April (Liszewski 1999).

Number of flower clusters (4.4 to 9.5 clusters per plant) and number of flowers (117.7 to 217.7 flowers per plant) was effected significantly by interaction year × production system, but only number of flower clusters varied significantly between genotypes under the full-season production system (Figure 1). The other interactions between studied variables were not significant. Similar differences between genotypes during two cropping seasons (summer and autumn) in number of flower clusters and flowers were observed Michiyama and Hayashi (1998). Depending on cropping systems formed flowers (208.5, 152.8) a small percentage of developed seeds (18.9%, 12.3%) were formed, respectively, but we found a significant correlation between number of developed seeds and grain yield ($r = 0.81^*$) and between number of developed seeds and number of flowers ($r = 0.37^*$), in both genotypes. ANOVA shows that production system, year, genotype and interactions significantly changed the number of developed seeds and grain yield (Table 2).

Authors (Aufhammer et al. 1994, Sugimoto and Sato 1999) number of developed seeds varied among genotypes and years. In our case, all interactions (year × production system, production system × genotype, year × genotype and year × genotype × production system) significantly influenced grain yield (Table 2). Cultivar Darja was significantly higher grain yield than the land race population in both years, and is preferred for full-season production system (Figure 3). Full-season plants from cultivar Darja formed from 41.5 to 64.3% more developed seeds than land race population, depending on year (Figure 2). Comparing grain yield between full-season (1752 kg.ha^{-1}) and stubble production system (1024 kg.ha^{-1}) showed sim-

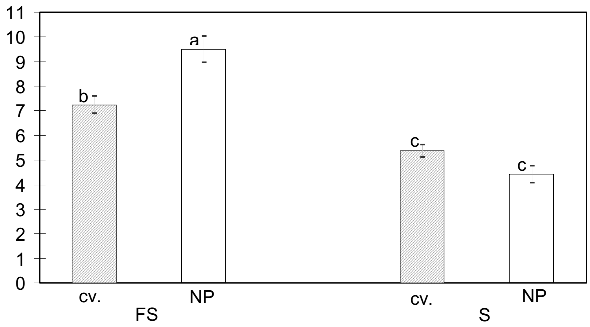

Figure 1. Number of flower clusters per plant

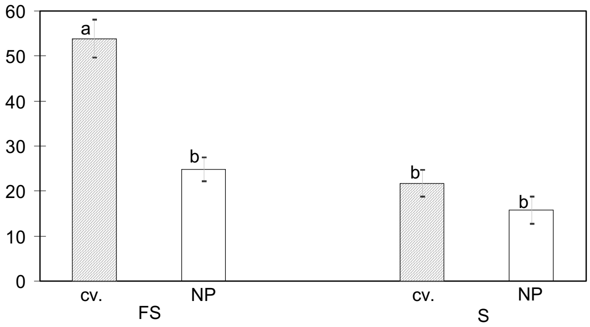

Figure 2. Number of developed seeds per plant

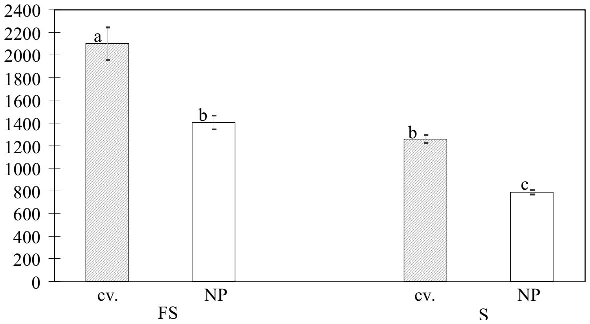

Figure 3. Grain yield (kg.ha^{-1}) of two buckwheat cultivars

NP – natural population, i.e. land race population, cv. – cultivar Darja, under two production systems (FS – full-season crop, S – stubble-crop); a, b, c – means of separate variables with different letters are significantly different at $P \leq 0.05$

ilar results to those of Aufhammer et al. (1994), when sowing date in May gave significant higher grain yield of 1500 kg.ha^{-1} than in August and April.

CONCLUSION

In addition to genotype and year, cropping system (i.e. vegetation period) affects buckwheat yield potential. Hence, the best yielding buckwheat genotypes should be determined separately for stubble-crop and full-season production system.

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ABSTRAKT

Výnosová schopnost dvou genotypů pohanky seté pěstované jako hlavní a strnisková plodina

Tradiční způsob pěstování pohanky (*Fagopyrum esculentum* L.) ve Slovinsku je formou strniskové plodiny, ale výnosnější způsob je formou hlavní plodiny. Genotypy přizpůsobené k pěstování jako strnisková plodina nemusí být vhodné jako plodina hlavní. Cílem studia bylo stanovit výnosovou schopnost dvou genotypů v uvedených produkčních systémech. Pokusy (metoda znáhodněných bloků) byly založeny v letech 1997 a 1998 v oblasti Podravje se dvěma nejvýznamnějšími genotypy pohanky (krajová populace a odrůda Darja). Pohanka pěstovaná jako hlavní plodina dosahovala většího indexu listové plochy (LAI), více květních hroznů, více vyvinutých semen a o 42 % vyšší výnos než varianty strniskové plodiny. Ačkoliv odrůda Darja měla o 10 % méně květních hroznů než krajová populace, počet kvítků a vyvinutých semen byl větší. O 35 % vyšší výnos odrůdy Darja byl spojen s větším LAI (4,0 oproti 2,3 u krajové populace). Výnosy odrůdy Darja průkazně převyšovaly krajovou populaci při pěstování jako hlavní plodina, zatímco výnosové diference mezi odrůdami nebyly průkazné u strniskové formy pěstování. Tyto výsledky dokazují, že výnosová schopnost genotypů by měla být stanovována odděleně podle pěstebního systému.

Klíčová slova: *Fagopyrum esculentum*; genotyp; pěstební systém; index listové plochy; výnos

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Corresponding author:

Assoc. Prof. Franc Bavec, University of Maribor, Faculty of Agriculture, 2000 Maribor, Slovenia, tel.: + 386 2 250 58 30, fax: + 386 2 229 60 71, e-mail: franci.bavec@uni-mb.si