Preliminary BAR-OF-WP4 report on

Do nutrient uptakes and grain yields differ between spring barley varieties grown for organic farming as mono-crop and in mixture

Characteristics of spring barley varieties for organic farming

Niels Erik Nielsen[1], Ingrid Kaag Thomsen[2] and Jørgen Berntsen[2]

[1]Plant Nutrition and Soil Fertility Laboratory, Department of Agricultural Sciences, The Royal Veterinary and Agricultural University, Thorvaldsensvej 40, DK-1871 Frederiksberg C
[2]Department of Agroecology, Danish Institute of Agricultural Sciences, Research Centre Foulum, Post Box 50, DK-8830 Tjele

Introduction

Data by Nielsen et al. 2003 indicated that the initial growth by spring barley seedling was restricted by moderate internal deficiency of phosphorus (P) and potassium (K). It appeared also that the barley varieties differed in their capability of P and K acquisition, that cropping of barley varieties in mixtures stabilized P and K acquisition and biomass production.
The present paper gives data on nutrient uptakes, biomass and grain production by 6 varieties and 2 mixtures of spring barley grown at 8 soil fertility levels.

Materials and Methods

The field experiment included six spring barley varieties Otira, Orthega, Landora, Brazil, Svani and NK96-300 (Norsk Korn) and two mixtures of these varieties: Mixture 1: (Otira, Orthega, Landora) and Mixture 2 (Brazil, Svani and NK96-300). The barley was grown at 8 different combinations of rotation and manure treatments as seen from Table 1a. An underseed of clover grass was sown about one week after barley sowing. Two cuts of the barley were taken (26-05-03 and 04-08-03) before harvest at maturity. The plant biomass in the second cut was divided into barley and grass + clover + weeds. Details of the field experiment, statistical design and analytical procedures are described elsewere, Nielsen et al. 2003.

Table 1a Nitrogen applications in manure and deep-litter in 2003

Field	Treatments kg ha^{-1}
4 year after clover-grass	None
	50 N in slurry
	100 N in slurry
	100 N in deep-litter
1 years after clover	None
	0 N in slurry
	60 N in slurry
	120 N in deep-litter

Split-plot in combination with an un-resolvable, incomplete block design
The field experiment included 8 treatments: 2 fields x (none, 2 levels of slurry and 1 level deep-litter). However, the size and shape of the main plots could not afford more than 6 subplots of barley varieties per plot. As the total numbers of subplots within each treatment were 24, it was possible to have 3 replicates of each combination of field, treatment and variety. An incomplete block design was then constructed that allows the varieties to be compared. The statistical model for the design is:

$$Y_{fbtv} = m + g_v + (ab)_{ft} + (abg)_{ftv} + C_{fb} + D_{fbt} + E_{fbtv}$$

where Y_{fbtv} is the response of variety v in treatment t in block b of field f, and $(ab)_{ft}$, is the effect of the combination of treatment t in field f; g_v is the main effect of variety v; and $(abg)_{ftv}$ is the interaction between combination of treatment t in field f and variety v. C_{fb} is the random effect by replicates of the original treatments within the field, D_{fbt} is the random effect of whole plots in the original experiments and E_{fbtv} is random effect of subplots. All random effects are assumed to be normal distributed with a constant variance and a mean equal to zero.

Main properties of the loam soil are shown in Table 1b

Table 1b Soil characteristics (Askegaard et al.1999).

Coarse Sand %	Fine Sand %	Silt %	Clay %	Organic Matter %	pH in 0.01 M $CaCl_2$	Olsen-P ppm	Exch. K ppm
33	46	10	8	3	6.0	29	58

Sampling, sample preparation and analyses were done as described by Nielsen et al. 2003.

Results and discussion

The data in Table 2 show that the main effects of variety and treatment on biomass and grain yields were significant whereas interactions between variety and treatment appears to be insignificant.

Table 2 Statistical significance (probability of none effect) of 8 treatments, Table 1a, and 8 spring barley variety/mixture (variety) on biomass and grain production

Effect	Biomass 30 days	Biomass 100 days	Grain 110 days
Treatment (t)	0.0001	0.0001	0.0001
Variety (v)	0.0001	0.0001	0.0001
t*v	0.61	0.89	0.49

Least square means of biomass and grain yield of Otira, Orthega, Landora, Brazil, Svani and NK96-300 and Mixture 1 (Otira, Orthega, Landora) and Mixture 2 (Brazil, Svani and NK96-300) at 8 treatments (Table 1a) can be seen in Table 3.

Table 3 Biomass of the barley cultivars 30 and 100 days after germination and grain yields. Mean of 8 treatments

No	Barley cultivars	Biomass, ton ha^{-1}		
		30 days	100 days	Grain
1	Otira	0.62	9.3	3.75
2	Orthega	0.50	9.8	4.22
3	Landora	0.46	9.8	4.04
4	Brazil	0.55	9.1	3.92
5	Svani	0.36	8.4	3.09
6	NK96-300	0.55	8.0	3.16
7	Mixture 1 (Otira + Orthega + Landora)	0.54	10.1	4.09
8	Mixture 2 (Brazil + Svani + NK96-300)	0.48	9.0	3.47
	Error	± 0.03	± 0.3	± 0.06

The data show that Otira,Orthega, Landora, Brazil and Mixture 1 had a higher production levels of biomass and grain than Svani, NK96-300 and Mixture 2.
The relation between soil fertility treatments and yield can be seen from the data in Table 4. It appears that increasing manure application increased yield. Hence the study is conducted under the conditions of moderate nutrient stress and in all probability nitrogen stress.

Table 4. Biomass production of 6 barley varieties and 2 mixtures of varieties 30 days after germination as affects by position in crop rotation and manure application in 2003

Years from clover grass	Manure application	Biomass, ton ha^{-1}		
		30 days	100 days	110 days
		Biomass	Biomass	Grain
1	None	0.26	8.3	2.97
	0N S	0.29	8.2	3.14
	60N S	0.44	10.1	3.74
	120N DL	0.37	8.2	3.72
4	None	0.57	8.1	3.50
	50N S	0.66	9.1	3.94
	100N S	0.85	10.1	4.54
	100N DL	0.61	9.6	4.21
	Error	± 0.03	± 0.3	± 0.08

Uptakes of N, P, S, K, Mg, Ca, Mn, Zn, Cu and Mo differed significantly between varieties (v) and treatments (t), Table 5. The interactions (v*t) were also significant for the uptakes of P, S, K, Mg, Ca, Mn, Zn, Cu and Mo but not for N.

Table 5 Statistical significance (probability of none effect) of 8 soil fertility treatments (Table 1a) and 8 spring barley variety/mixture (variety) on uptakes of nitrogen (N), phosphorus (P) sulphur (S), potassium (K), magnesium (Mg), calcium (Ca), manganese (Mn), zinc (Zn), copper (Cu) and molybdenum (Mo) 100 days after germination

Effect	N	P	S	K	Mg	Ca	Mn	Zn	Cu	Mo
v	0.0001	0.03	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
t	0.0001	0.0001	0.0001	0.0001	0.0008	0.0001	0.0001	0.0001	0.0001	0.0001
v*t	0.49	0.03	0.0001	0.014	0.10	0.0001	0.0001	0.0001	0.0019	0.0001

Details of the differences between the varieties in nutrient uptakes 100 days after germination can be seen from Figures 1 to 4. Looking into N, P and S uptakes by Otira, Orthega, Landora and Brazil belonging to the same platform of biomass/grain production, it appears that S uptakes by Orthega and Landora were more than 20% higher than S uptakes by Otira and Brazil. It is notable that Landora under the prevailing conditions of N stress was able to acquire 10% more N than e.g. Brazil. On the other hand Brazil was able to acquire 10% more P than Landora. Figure 2 shows the uptakes of K, Mg, Ca, Mn, Zn, Cu and Mo as a fraction of their mean. It is seen from the Figure that uptakes of K and Mg were higher by Orthega, Landora and Brazil than by Otira, Svani and NK96-300 e.g. K uptake by Landora was 15% higher than by Otira. It is notable that Ca uptake by Otira was 25% lower than the Ca uptake by Orthega. It is also notable that Zn uptake by Svani was 35% lower than Zn uptake by Orthega, and that Cu uptake by Brazil was 20% higher than Cu uptakes by Orthega and Landora.

Nutrient uptakes by Otira, Orthega and Landora, grown as mixture (Mix.1), and Brazil, Svani and NK96-300 (Mix.2) were significantly higher than the mean of the components (mono-crops). Details of the differences between mono-crop and mixtures of the barley varieties in N, P, S, K, Mg, Ca, Mn, Zn, Cu and Mo uptakes 100 days after germination can be seen from Figure 3 and 4, and Table 7. It appears from the data in Table 7 that biomass production increased by 8 – 10% whereas the increases in nutrient uptakes in most cases were considerably higher. Hence barley varieties in mixture (more biodiversity) stimulates nutrient uptakes and biomass production.

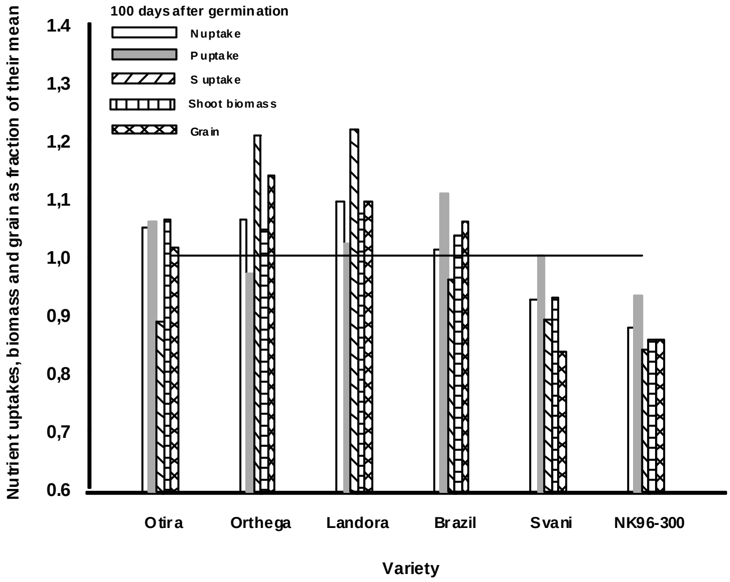

Figure 1 Uptakes of N, P and S, and biomass production 100 days and grain yield by 6 cultivars of spring barley 100 days after germination

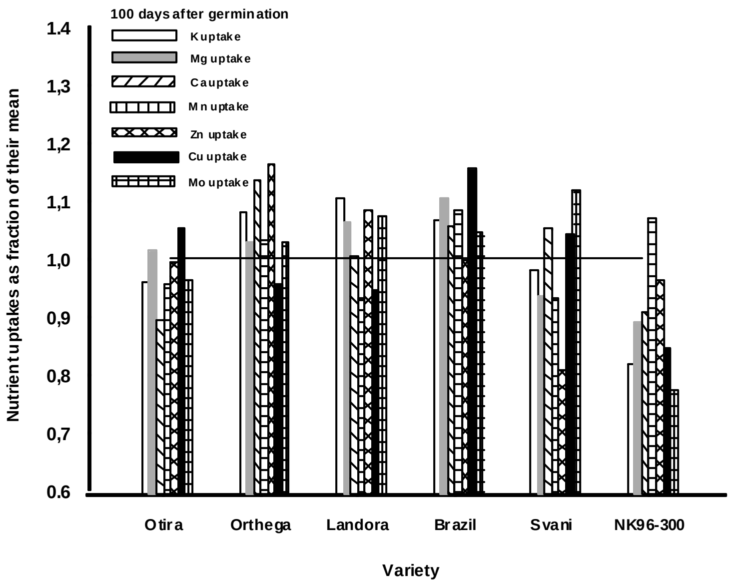

Figure 2 Uptakes of K, Mg, Ca, Mn, Zn, Cu and Mo by 6 cultivars of spring barley 100 days after germination

Table 6 Statistical significance (probability of none effect) of cropping of barley varieties* in mixtures on uptakes of nitrogen (N), phosphorus (P) sulphur (S), potassium (K), magnesium (Mg), calcium (Ca), manganese (Mn), zinc (Zn), copper (Cu) and molybdenum (Mo) 100 days after germination at 8 soil fertility treatments (Table 1a).

Effect	N	P	S	K	Mg	Ca	Mn	Zn	Cu	Mo
Mix. 1	0.29	0.001	0.0001	0.18	0.03	0.02	0.30	0.0009	0.07	0.0001
Mix. 2	0.81	0.09	0.0001	0.07	0.02	0.04	0.10	0.0001	0.52	0.05

*) Mix. 1 = Otira, Orthega and Landora as mixture versus mean of corresponding mono-cropping;
Mix. 2 = Brazil, Svani and NK96-300 as mixture versus mean of corresponding mono-cropping.

Table 7 Increases (%) in uptakes of nitrogen (N), phosphorus (P) sulphur (S), potassium (K), magnesium (Mg), calcium (Ca), manganese (Mn), zinc (Zn), copper (Cu) and molybdenum (Mo) 100 days after germination at 8 soil fertility treatments (Table 1a) due to cropping* in mixture.

Crop	N	P	S	K	Mg	Ca	Mn	Zn	Cu	Mo	Biomass	Grain
Mix. 1	8	10	24	8	10	12	6	16	10	24	8	2
Mix. 2	8	12	18	7	15	15	13	17	9	15	10	2

*) Mix. 1 = Otira, Orthega and Landora as mixture versus mean of corresponding mono-cropping;
Mix. 2 = Brazil, Svani and NK96-300 as mixture versus mean of corresponding mono-cropping.

Conclusions

Manure application increased yield. Hence the study was conducted under the conditions of moderate nutrient stress and in all probability nitrogen stress.

Under this condition nutrient uptakes, biomass production and grain yields did vary between Otira, Orthega, Landora, Brazil, Svani, NK96-300, Mixture 1 (Otira, Orthega, Landora) and Mixture 2 (Brazil, Svani and NK96-300). Interaction between variety and soil fertility treatments were also significant. These findings open new possibilities for selection or plant breeding for genotypes with improved capability of nutrient acquisition from soils at different soil fertility levels e.g. in organic farming.

Cropping of barley varieties in mixtures seems to increase (stimulate) nutrient uptakes (N, P, S, K, Mg, Ca, Mn, Zn, Cu and Mo) and biomass production.

References

Askegaard M, Eriksen J, Soegaard K and Holm S . Nutrient management and plant production in four organic dairy farming systems. DJF Rapport Nr. 12, 1-112. 1999. Danmarks JordbrugsForskning, Forskningscenter Foulum, Postboks 50, 8300 Tjele.
Ref Type: Report

Nielsen N E, Ingrid Kaag Thomsen I K and Berntsen J 2003 Characteristics of spring barley varieties for organic farming Nutrient acquisition and crop performance, p. 1-7
http://orgprints.org/00001453/01/BAR-OF-NEN-O3-paper1.doc

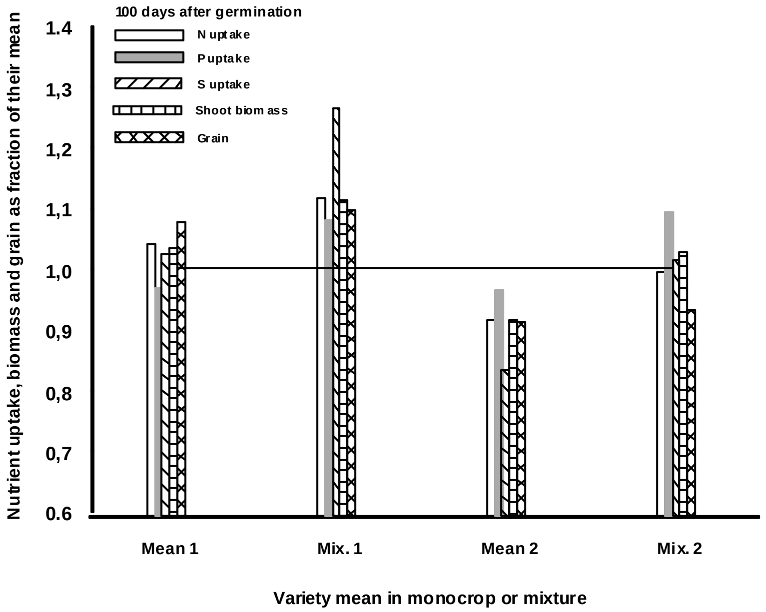

Figure 3 Mean of nutrient uptake and biomass production of 3 cultivars as mono-crops and corresponding mixtures 100 days after germination

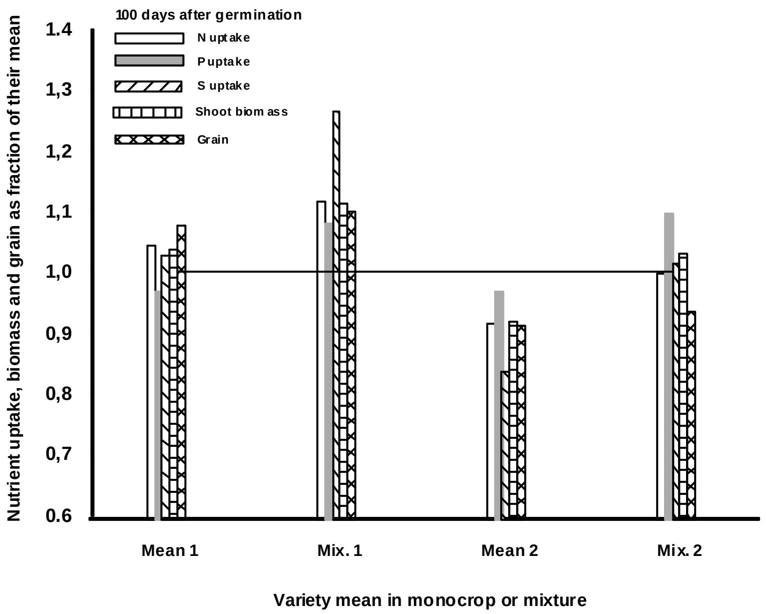

Figure 4 Mean of nutrient uptake and biomass production of 3 cultivars as mono-crop and corresponding mixtures 100 days after germination