Research Article • DOI: 10.1515/ijafr-2018-0001 IJAFR • 57 • 2018 • 1-8

Irish Journal of Agricultural and Food Research

A comparison of husked and naked oats under Irish conditions

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Abstract

During the harvesting of husked oats (*Avena sativa *L.), the kernel remains tightly enclosed by a lignified lemma and palea, collectively termed the husk or hull. In naked oats, which are the same species as husked oats, the lemma is much less lignified and the kernel threshes free during harvesting. The absence of the largely indigestible husk increases the nutritive value of naked oats compared to that of husked oats, particularly for non-ruminants and poultry. There is little information regarding the potential of naked oats as an arable crop in Ireland. The objective of this study was to determine the productivity of naked oats under Irish conditions. Field experiments were carried out in the south east of Ireland to compare the grain yield and grain quality of both autumn-sown and spring-sown naked and husked oat cultivars. Grain yield of naked oat cultivars was significantly lower than that of husked oat cultivars, irrespective of whether they were autumn sown or spring sown. However, when the kernel yield of husked oat cultivars was estimated, differences in yield between the two types were much smaller, and in some cases, kernel yield of naked oat cultivars exceeded that of husked oat cultivars. Grain quality, as indicated by hectolitre weight and grain N concentration, was generally greater for naked oat cultivars than for husked oat cultivars. It is concluded that under Irish conditions, naked oats have the potential to produce kernel yields equivalent to husked oats. The grain produced is of high quality and may be particularly suited for the nutrition of non-ruminants.

Keywords

grain quality • husked oats • naked oats • yield

Introduction

On a world scale, oats ranks sixth in terms of cereal production after maize, rice, wheat, barley and sorghum (FAOSTAT, 2017). In Ireland, oats (*Avena sativa* L.) is the third most important cereal crop and occupies a much smaller area than either wheat or barley but is nonetheless an economically important crop. Oats are resistant to the main strain of take-all (*Gaeumannomyces graminis* var *tritici*) that infects wheat and barley crops and can therefore act as a useful rotational crop to reduce the effects of take-all in succeeding crops. Oats generally tolerate acidic soils and moist climates better than either wheat or barley, making them ideally suited to Irish growing conditions. They are grown for both animal and human nutrition. However, the area of oats is restricted by limited market outlets.

Oat grain has a number of nutritional benefits compared to other cereals (Marshall *et al.*, 2013). It has a high lipid content compared to wheat and barley, which comprises principally unsaturated oleic and linoleic fatty acids as well as high concentrations of the amino acids lysine, methionine and cysteine (Morris, 1990; Welch, 1995). For human nutrition, they are a source of soluble fibre and β-glucans, both of which can have positive effects on health (Anderson and Bridges, 1993).

The vast majority of oats currently grown in Ireland are husked oats, whereby the caryopsis or kernel is enclosed by a lignified lemma and palea, collectively termed the husk. The kernel does not thresh free of these husks during harvesting, and subsequent removal of these husks requires considerable energy input. The presence of these husks, which have lower digestibility than the kernel, means that husked oats have lower nutritional value than other cereals, particularly for non-ruminants that have limited ability to deal with high levels of dietary fibre (MacLeod *et al.*, 2008).

In naked oats, which are the same species as husked oats, lignification of the lemma is much less than that in husked oats, such that at harvest, the lemma is thinner and less rigidly curved around the kernel, allowing the kernel to thresh free during harvest (Ougham *et al.*, 1996). While all kernels of earlier cultivars did not always thresh free of the husk, more recent cultivars have been shown to completely thresh free of the husk (Valentine *et al.*, 1997). The expression of the naked phenotype is thought to be highly heritable but can be affected

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by environmental conditions, particularly temperature (Lawes and Boland, 1974; Ubert *et al.*, 2017). In the absence of the husk, the metabolisable energy of the naked oat kernel can be comparable to or higher than that of wheat (MacLeod *et al.*, 2008). Naked oat kernels have also been shown to have a higher content of metabolisable energy, lipids, linoleic acid, protein, essential amino acids and starch than husked oat cultivars (Welch, 1995; Givens *et al.*, 2004; Biel *et al.*, 2009). These characteristics make naked oats potentially more suitable as a feed source than other cereals particularly for poultry (Hsun and Maurice, 1992; MacLeod *et al.*, 2008), and some authors have reported that naked oats have high digestibility and metabolisable energy when used as a feed source for ruminants (Givens and Brunnen, 1987).

In addition to reducing the nutritional value of the grain, the presence of husks reduces the bulk density, or specific weight, of husked oats in comparison with naked oats. This means that transportation cost associated with husked oats will be higher than that for naked oats. In addition, specific weight is a key measure of quality used when oats are traded; thus, a higher specific weight, due to the absence of the husks, should result in a higher grain price. However, the presence of a husk can protect the kernel from damage, and hence, kernels of naked oats may be more susceptible to damage during threshing, handling and transportation, which could lead to a deterioration in quality, particularly in their high oil content. Damage to the exposed kernel has been shown to affect subsequent germination of naked oat seed (Valentine and Hale, 1990).

The yield of naked oat cultivars has generally been found to be lower than that of husked oat cultivars (Peltonen-Sainio, 1994, 1997; Kangas *et al.*, 2001; Wade and Maunsell, 2004). Results of variety evaluation experiments have indicated that the yield of naked oat cultivars is typically 70%–80% that of husked oat cultivars (AHDB, 2017). However, when kernel yields are compared i.e. after removal of the husk from husked oat cultivars, yield differences between naked and husked oats are reduced considerably (Peltonen-Sainio, 1994).

The potential of naked oats grown under Irish conditions remains unexplored. The objective of this study was to compare yield and quality of both autumn-sown and spring-sown naked oat cultivars with those of conventional husked oat cultivars under Irish conditions.

Materials and methods

Experiments were carried out to compare both autumn-sown and spring-sown naked oat cultivars with husked oat cultivars. For the autumn-sown comparison, a randomised complete block experiment with five cultivars and five replications was carried out over three seasons, 2004/2005, 2005/2006 and 2006/2007, referred to hereafter as 2005, 2006 and 2007, respectively, at the Teagasc, Crops Research Centre, Carlow, Ireland (52.86° N, 6.92° W, 62 m a.m.s.l.). In each year, two cultivars of husked oats and three cultivars of naked oats were included. Cultivars varied between seasons according to seed availability. The husked oat cultivars were Barra in all three seasons, Evita in 2005 and 2006 and Corrib in 2007. The naked oat cultivars were Hendon and Expression in all three seasons, Grafton in 2005 and Racoon in 2006 and 2007. The naked oat cultivars originated from a UK naked oat breeding programme and thus were selected under similar climatic conditions to Irish conditions. Hendon, Grafton and Expression were selected on the basis of having a commercial recommendation in the UK (HGCA, 2004). Racoon was included as an example of a cultivar with an elevated oil content (MacLeod *et al.*, 2008). The chosen husked oat cultivars were the main cultivars available for commercial production. Experiments were sown on 2 November 2004, 28 October 2005 and 16 October 2006. The seed rate used was 300 seeds/m^2 for all cultivars in all years; differences in germination between cultivars were not determined and were not taken into account when determining seed rate.

Crops received 170 kg N/ha in 2005 and 135 kg N/ha in the remaining seasons. Herbicides, insecticides and fungicides were applied according to standard farm practice. In 2006 and 2007, due to the faster development of the husked oats compared to the naked oats, growth regulator was applied to the husked oats 10–20 days earlier than to the naked oat cultivars. Growth regulator was applied to all cultivars on the same day in 2005. All other inputs were applied to both cultivar types at the same time. Crops were harvested on August 3 in 2005 and 2006 and on August 2 in 2007.

For the spring-sown comparison, two husked and two naked oat cultivars were included in a randomised complete block design in 2007 and 2008. There were six replications in both seasons. The naked oat cultivars were Bullion and Zuton in both years; the husked oat cultivars were Barra and Evita in 2007 and Chimene and Corrib in 2008. The experiments were sown on 20 March 2007 and 25 March 2008. Crops received fertiliser and pesticide inputs according to standard farming practice. Crops were harvested on 28 August 2007 and 1 September 2008.

Weather data (temperature, rainfall and solar radiation) were recorded at the Met Éireann weather station, which was located within 1 km of the location of the experiments in each season. Crop height was measured soon after the beginning of grain fill by measuring the distance from the soil surface to the tip of the panicle in 5–10 locations per plot. At crop maturity, just prior to combine harvest, plants in two adjacent 50 cm row lengths were cut at ground level at two locations in each plot and bulked together. For the autumn-sown experiments, the total number of panicles in each sample

was recorded and the panicle population density (panicles/m^2) was calculated, taking row spacing as 15.4 cm. Samples were then threshed to separate grain and straw, and both fractions were dried at 70°C for 48 h and their dry weight was determined. Harvest index (HI) was determined as the ratio of grain dry matter (DM) and total DM for each sample. Thousand grain weight was determined for each sample using an electronic grain counter (Contador; Pfeuffer, Kitzingen, Germany) and expressed at 85% DM. The mean number of grains per panicle was calculated by dividing the total number of grains in each sample by the number of panicles in the sample. Both grain and straw were milled to pass through a 2-mm screen before determining the nitrogen concentration of both fractions using the Dumas combustion method (LECO FP428; LECO Corporation, St. Joseph, MI, USA). Components of yield or N content of the straw fraction was not determined for spring-sown experiments in any season. N content of the straw and grain fractions was calculated as the product of the respective sample DM and N concentration. Nitrogen harvest index (NHI) for each sample was calculated as the ratio of grain N content to total (straw and grain) sample N content. Grain N accumulation was determined as the product of combine-harvested grain yield and grain N concentration. Total crop N accumulation (CNU) was calculated as the quotient of grain N accumulation and NHI. Physiological efficiency (PE) of nitrogen use was determined as the quotient of grain yield and total CNU.

Grain yield (adjusted to 85% DM) was determined using a small plot combine harvester equipped with weighing equipment. Hectolitre weight was determined on samples taken during combine harvest, after removing any straw present, using a chondrometer.

Analysis of variance, with cultivar and replication included as fixed effects, was performed on all measured variables using the mixed procedure of SAS 9.3 with $\alpha = 0.05$ (SAS Institute Inc., Cary, NC, USA). When significant effects of cultivar were found, least-squares mean values were separated by independent pairwise *t*-tests with $\alpha = 0.05$.

Results

Mean values of monthly air temperature and cumulative rainfall and solar radiation for the main growing season (March–August) of each season are presented in Table 1. In 2005 and 2006, rainfall was lower than normal in June, July and August; rainfall was also lower than normal in April 2006. In the remaining months of these years, rainfall was similar to or higher than normal. In both 2007 and 2008, rainfall was lower than normal in April and May and above normal in the remaining months of the growing season.

With the exception of 2007, when temperature was higher than normal, temperature in April was close to the 30-year mean temperature in all seasons. Temperature in May was lower than normal in 2005, greater than normal in 2008 and similar to normal in 2006 and 2007. Temperature in June and July was greater than normal in 2005 and 2006 and similar to or lower than normal in 2007 and 2008.

Total cumulative solar radiation between March and August was highest in 2006 and 2007, where levels of radiation were similar in both years. Cumulative solar radiation was lower

Table 1. Mean monthly air temperature, cumulative monthly rainfall and cumulative monthly solar radiation recorded at Oak Park in 2005, 2006, 2007 and 2008 (source: www.met.ie)

Month	Rainfall (mm)					Temperature (°C)					Solar radiation (J/cm²)				
	2005	2006	2007	2008	LTA	2005	2006	2007	2008	LTA	2005	2006	2007	2008	LTA
March	62.4	87.9	73.4	86	63.4	8.0	5.8	6.5	6.1	6.9	21,361	19,828	24,497	26,963	25,415
April	76.5	27.2	17.1	32.5	55.9	8.4	8.6	11.1	8.0	8.4	33,872	42,197	46,689	38,513	39,771
May	70.4	85.6	38.3	37.1	59.8	10.5	11.1	11.7	12.6	11	47,812	41,481	49,527	48,898	52,075
June	30.2	47.3	110.8	88	60.8	14.7	15.1	12.3	13.1	13.7	46,041	51,318	41,953	48,539	51,128
July	50.7	31.4	128.8	140	58.7	16.0	17.4	14.8	11.9	15.6	43,644	55,635	47,730	44,096	50,371
August	41.8	36.5	106.4	143.7	71.9	13.8	15.6	15.3	15.8	15.3	41,186	39,162	39,550	31,033	41,749

LTA values for rainfall and temperature are monthly mean values for the period 1981–2010 recorded at Oak Park. LTA values for solar radiation are monthly mean values for 1979–2008 recorded at Kilkenny.
LTA = long-term average.

in 2005 than in 2008, with cumulative solar radiation in both years being lower than that in 2006 and 2007.

Autumn-sown experiments

The mean yield of the two husked oat cultivars was 10.1, 9.9 and 9.8 t/ha in 2005, 2006 and 2007, respectively (Table 2). The grain yield of both husked oat cultivars was significantly higher than that of all three naked oat cultivars in all three seasons. The grain yield of the naked oat cultivars ranged between 64% and 84% that of the mean yield of the two husked oat cultivars over the three seasons. Expression was the highest yielding naked oat cultivar in all three seasons. Differences in yield between the two types were largely due to differences in 1,000 grain weight, which was significantly lower for all three naked oat cultivars compared to the two husked oat cultivars in all three seasons. Differences between the naked and husked oat cultivars in terms of panicle population density and grains/panicle were not consistent. Panicle population and grains/panicle of any of the naked oat cultivars were not significantly different from those of the husked oat cultivar Barra in 2005 and 2006. In 2007, the three naked oat cultivars had a significantly higher panicle population and significantly lower grains/panicle than those of Barra. The husked oat cultivar Corrib had a significantly lower panicle population than all three naked oat cultivars but had number of grains per panicle similar to two of the naked oat cultivars and significantly more grains/panicle than the third naked oat cultivar (Racoon). Evita had a similar or significantly higher panicle population compared to the three naked oat cultivars; it had similar or significantly lower grains/panicle than the three naked oat cultivars.

Hectolitre weight of all three naked oat cultivars was significantly higher than that of both husked oat cultivars in 2005 and 2006 (Table 3). In 2006, one of the naked oat cultivars, Hendon, had hectolitre weight similar to the husked oat cultivar Barra and significantly higher hectolitre weight than the husked oat cultivar Evita. In 2006, the remaining two naked oat cultivars had significantly higher hectolitre weight than both husked oat cultivars. The mean hectolitre weight of the three naked oat cultivars was 6.5 kg/hL, 4.5 kg/hL and 8.9 kg/hL greater than the mean hectolitre weight of the husked oat cultivars in 2005, 2006 and 2007, respectively.

Grain nitrogen concentration of all three naked oat cultivars was significantly higher than that of the two husked oat cultivars in 2005 and 2006 (Table 3). In 2007, differences between the cultivar types were less pronounced. In that year, grain nitrogen concentration of two of the naked oat cultivars, Expression and Hendon, did not differ significantly from that of the two husked oat cultivars; grain nitrogen concentration of the third naked oat cultivar, Racoon, was significantly higher than that of Barra but similar to that of Corrib.

Differences in height appeared to be more related to cultivar rather than cultivar type as there were no consistent differences in height between naked and husked oat types (Table 3).

All naked oat cultivars had a significantly lower HI compared to the husked oat cultivars in 2005 and 2006 (Table 3). In 2007, the naked oat cultivar Expression had a HI that was not significantly different from that of the husked oat cultivar Barra but significantly lower than that of Evita. The naked oat cultivars Hendon and Racoon had a significantly lower HI than both husked oat cultivars in that year. The mean HI of

Table 2. Grain yield and components of yield of autumn-sown husked and naked oat cultivars over three growing seasons

Cultivar	Grain yield (t/ha @ 85% DM)			Panicle population density (ears/m^2)			Grains/panicle			1,000 grain weight (g @ 85% DM)		
	2005	2006	2007	2005	2006	2007	2005	2006	2007	2005	2006	2007
Husked												
Barra	9.70 b	9.52 b	9.58 a	292.9 bc	350.0	215.6 c	105.2 a	111.1	104.1 a	31.6 a	28.2 b	35.3 a
Evita	10.56 a	10.20 a	-	368.2 a	416.9	-	91.3 b	92.2	-	32.0 a	31.0 a	-
Corrib	-	-	9.96 a	-	-	303.2 b	-	-	81.2 b	-	-	36.1 a
Naked												
Expression	8.51 c	7.30 c	7.69 b	288.3 bc	339.0	359.1 a	112.4 a	112.3	71.6 b	27.0 b	23.4 c	30.8 b
Hendon	7.67 d	6.41 d	7.54 b	345.5 ab	403.9	362.3 a	106.3 a	102.8	71.4 b	22.7 d	21.6 c	26.8 c
Racoon	-	6.63 d	6.25 c	-	383.1	377.9 a	-	98.8	55.3 c	-	21.7 c	29.4 b
Grafton	7.38 d	-	-	277.3 c	-	-	105.4 a	-	-	24.7 c	-	-
P[1]	***	***	***	*	ns	***	*	ns	***	***	***	***

Mean values followed by the same letter are not significantly different ($P > 0.05$). [1]*P* indicates the significance of the variety effect in the analysis of variance.
DM = dry matter; ns = not significant.

the naked oat cultivars was 0.07–0.1 lower than that of the husked oat cultivars over the three seasons.

When grain N accumulation, the product of grain yield and grain N concentration, was calculated, the naked oat cultivars had similar or lower grain N accumulation than the husked oat cultivars (Table 4). In 2005, two of the naked oat cultivars, Hendon and Grafton, had a significantly lower grain N accumulation than both husked oat cultivars, while grain N accumulation of the third naked oat cultivar, Expression, was similar to that of Barra but significantly lower than that of Evita. In 2006, grain N accumulation of all three naked oat cultivars was similar to that of Barra but significantly lower than that of Evita. In the third season, all three naked oat cultivars had a significantly lower grain N accumulation when compared to Corrib; when compared to Barra, both Expression and Racoon had a significantly lower grain N accumulation while Hendon had similar grain N accumulation.

There were no consistent differences in total CNU between naked and husked oat cultivars (Table 4). In 2005, the naked oat cultivars Hendon and Grafton had CNU similar to the husked oat cultivar Barra, while the third naked oat cultivar had CNU similar to Evita. There was no significant effect of cultivar on CNU in 2006. In 2007, CNU of all three naked oat cultivars was not significantly different from that of Barra but was significantly lower than that of Corrib.

While NHI values for naked oat cultivars were often lower than those for the husked oat cultivars, the differences were not always statistically significant (Table 4).

Table 3. Grain quality, crop height and HI of autumn-sown husked and naked oat cultivars over three growing seasons

Cultivar	Hectolitre weight (kg/hL)			Grain N concentration (% @ 100% DM)			Height (cm)			HI		
	2005	2006	2007	2005	2006	2007	2005	2006	2007	2005	2006	2007
Husked												
Barra	56.4 b	54.4 c	60.6 c	2.01 b	1.62 c	1.67 c	129.8 b	137.0 a	133.3 a	0.49 a	0.46 b	0.44 ab
Evita	55.0 b	52.8 d	-	2.06 b	1.72 c	-	116.6 c	120.6 b	-	0.50 a	0.49 a	-
Corrib	-	-	57.7 d	-	-	1.92 ab	-	-	132.8 a	-	-	0.46 a
Naked												
Expression	62.4 a	57.8 b	68.2 b	2.32 a	2.11 b	1.71 bc	146.0 a	134.8 a	122.1 b	0.39 b	0.39 c	0.41 bc
Hendon	61.4 a	54.7 c	68.0 b	2.35 a	2.35 a	1.82 bc	110.1 d	97.8 c	90.6 c	0.40 b	0.38 cd	0.40 c
Racoon	-	61.7 a	72.2 a	-	2.31 a	2.10 a	-	135.4 a	132.6 a	-	0.34 d	0.32 d
Grafton	62.7 a	-	-	2.43 a	-	-	118.7 c	-	-	0.38 b	-	-
P[1]	***	***	***	***	***	**	***	***	***	***	***	***

Mean values followed by the same letter are not significantly different ($P > 0.05$). [1]*P* indicates the significance of the variety effect in the analysis of variance.
HI = harvest index; DM = dry matter.

Table 4. Accumulation and PE of autumn-sown husked and naked oat cultivars over three growing seasons

Cultivar	CNU (kg N/ha)			Grain N accumulation (kg N/ha)			NHI			PE (kg grain DM/kg N)		
	2005	2006	2007	2005	2006	2007	2005	2006	2007	2005	2006	2007
Husked												
Barra	207.7 b	164.4	169.9 ab	165.7 b	130.6 b	135.6 b	0.80	0.79 b	0.80 ab	39.7 a	49.2 a	48.5 a
Evita	234.6 a	180.1	-	185.1 a	148.9 a	-	0.79	0.83 a	-	38.4 a	48.2 a	-
Corrib	-	-	195.1 a	-	-	162.2 a	-	-	0.83 a	-	-	43.5 ab
Naked												
Expression	222.7 a	166.5	145.3 b	167.9 b	130.8 b	112.0 c	0.75	0.79 b	0.77 bc	32.6 b	37.3 b	45.3 ab
Hendon	202.9 b	162.4	152.9 b	153.2 c	128.1 b	117.0 bc	0.76	0.78 b	0.77 bc	32.2 b	33.3 c	42.3 b
Racoon	-	169.4	151.5 b	-	130.2 b	111.8 c	-	0.77 b	0.74 c	-	33.4 c	35.3 c
Grafton	201.9 b	-	-	152.2 c	-	-	0.75	-	-	31.1 b	-	-
P[1]	**	Ns	**	***	*	***	ns	**	**	***	***	***

Mean values followed by the same letter are not significantly different ($P > 0.05$). [1]*P* indicates the significance of the variety effect in the analysis of variance.
PE = physiological efficiency; CNU = crop N accumulation; NHI = nitrogen harvest index; ns = not significant.

PE, the amount of harvested grain DM produced per kilogram of accumulated nitrogen, was significantly lower for all naked oat cultivars when compared to the husked oat cultivars in 2005 and 2006 (Table 4). In 2007, PE of Racoon was significantly lower than that of both husked oat cultivars and PE of Hendon was significantly lower than that of Barra but was not significantly different from that of Corrib. PE of Expression was not significantly different from that of either husked oat cultivar in 2007.

Spring-sown experiments

Results from spring-sown experiments are presented in Table 5. Yield of both spring-sown naked oat cultivars was significantly lower than that of the husked oat cultivars in both seasons. The mean yield of the two naked oat cultivars was 82% and 76% compared to the mean yield of the husked oat cultivars in 2007 and 2008, respectively. Hectolitre weight of both naked oat cultivars was significantly higher than that of the husked oat cultivars in both seasons. The difference in hectolitre weight between the naked and husked oat cultivars was large in both seasons; the mean hectolitre weight of the two naked oat cultivars was 13.6 and 15.3 greater than the mean hectolitre weight of the two husked oat cultivars in 2007 and 2008, respectively. Both naked oat cultivars had a significantly lower 1,000 grain weight than both husked oat cultivars in both seasons. Grain N concentration was only measured in 2007 when both naked oat cultivars had a significantly higher grain N concentration than the husked oat cultivar Barra. The naked oat cultivar Bullion had a significantly higher grain N concentration when compared to the husked oat cultivar Barra but not when compared to Evita. The HI of both naked oat cultivars was significantly lower than that of both husked oat cultivars in both seasons. The naked oat cultivar Zuton was significantly shorter than both husked oat cultivars in both seasons and was also significantly shorter than the naked oat cultivar Bullion. Height of Bullion was similar to that of both husked oat cultivars in 2008 and similar to that of Evita but significantly shorter than that of Barra in 2007.

Discussion

The grain yield of the husked oat cultivars obtained in this study was 1–2 t/ha greater than both national mean yields and yields recorded in national variety evaluation trials for husked oats (CSO, 2008; DAFM, 2008). Comparison of naked oat cultivar yields with commercial yields was not possible since only a limited area of naked oats was grown commercially in Ireland in these years and yield data were not recorded.

The lower grain yields obtained from both autumn- and spring-sown naked oat cultivars when compared to husked oat cultivars obtained in this study are in line with the findings of other studies (Peltonen-Sainio, 1994, 1997; Kangas *et al.*, 2001; Wade and Maunsell, 2004). The grain yield recorded for the husked varieties included the husks in addition to the kernel. The kernel content of the husked oats was not determined in this study. However, official variety evaluation trials indicated that the kernel yields of the husked varieties used in this study were typically between 70% and 75% (DAFM, 2008, 2009) and that this value is not subject to large environmental or management influences (Browne *et al.*, 2003). In these experiments, yield of the naked oat cultivars ranged between 64% and 84% than that of the husked oat cultivars. This indicates that if the grain yield of the husked oat cultivars is adjusted for the husk content, to give kernel yield, and the naked oat cultivars are assumed to have no husks

Table 5. Grain yield, grain quality, height and HI of spring-sown husked and naked oat cultivars over two growing seasons

Cultivar	Yield (t/ha @ 85% DM)		Hectolitre weight (kg/hL)		1000 grain weight (g @ 85% DM)		Grain N concentration (% @ 100% DM)	Height (cm)		HI	
	2007	2008	2007	2008	2007	2008	2007	2007	2008	2007	2008
Husked											
Barra	7.14 b	-	53.7 b	-	34.3 b	-	1.58 c	115.4 a		0.48 b	
Evita	7.46 a	-	52.4 b	-	38.6 a	-	1.69 bc	106.5 b		0.51 a	
Chimene	-	8.14 a	-	57.1 b	-	31.5 a	-		106.6 a		0.48 a
Corrib	-	7.83 a	-	57.3 b	-	31.2 a	-		109.6 a		0.47 a
Naked											
Bullion	5.85 c	6.14 b	66.3 a	72.6 a	26.8 c	25.4 b	2.00 a	108.2 b	106.5 a	0.42 c	0.39 b
Zuton	6.05 c	5.97 b	66.9 a	72.3 a	27.5 c	26.0 b	1.91 ab	101.2 c	99.1 b	0.42 c	0.38 b
P[1]	***	***	***	***	***	***	**	***	***	***	***

Mean values followed by the same letter are not significantly different ($P > 0.05$). [1]*P* indicates the significance of the variety effect in the analysis of variance.
HI = harvest index; DM = dry matter.

present in the harvested material, differences in kernel yield between the husked and naked oat cultivars are often small and in some cases, the naked oat cultivars give a greater kernel yield than the husked oat cultivars. The finding that differences in yields were most closely related to differences in 1,000 grain weight rather than panicle population density or numbers of grains per panicle provided further evidence that the main reason for the difference in yields between the husked and naked oat cultivars was the presence of the husk as the husk will add to the weight of each grain.

Peltonen-Sainio (1994) found that the higher yields observed for husked oat cultivars compared to naked oat cultivars was due to a greater number of panicles per square metre, which she attributed to greater plant emergence of the husked oat cultivars. Even though both cultivar types were sown at the same seeding rate in these experiments and naked oats are known to often have lower germination than husked oats (Valentine and Hale, 1990), naked and husked autumn-sown oat cultivars were generally not consistently different in terms of panicle density in two seasons, and in the third season, the naked oat cultivars had higher panicle density. This suggests that there was either no difference in establishment in these experiments (plant establishment was not determined) or the naked oat cultivars produced more tillers than the husked oat cultivars to make up for any differences in establishment. Given that the number of panicles produced per square metre was greater than the number of seeds sown per square metre, it is clear that both cultivar types produced tillers in this study, whereas in the study of Peltonen-Sainio (1994), tillering was likely to have been inhibited by the longer day lengths experienced in the more northerly environment. The lower HI of the naked oat cultivars observed for both autumn-sown and spring-sown crops was also in agreement with the findings of Peltonen-Sainio (1994), which again indicated that the presence of the husk was the principal reason for differences between the cultivar types.

The principal quality criterion used when oats are traded in Ireland is hectolitre weight. In these studies, hectolitre weight of naked oat cultivars was considerably higher than that of the husked oat cultivars. AHDB (2017) and Brand *et al.* (2003) also reported higher hectolitre weights for naked oats compared to husked oats. Similarly, protein content of the grain was significantly higher for naked oat cultivars when compared to the husked oat cultivars. Higher grain N concentrations in naked oat cultivars compared to husked oat cultivars has been reported in a number of studies (Brand *et al.*, 2003; Givens *et al.*, 2004; Biel *et al.* 2009). However, some authors have reported that when the husk is removed from husked oats, the quality of the resulting kernels is similar to that of naked oats (Peltonen-Sainio *et al.*, 2004).

The lack of consistent differences in terms of CNU suggests that both cultivar types have similar ability to recover N from the soil. Similarly, the absence of consistent differences in the NHI suggests that both cultivar types have similar ability to transfer accumulated nitrogen to the harvested grain. This in turn indicates that the higher grain N concentration recorded for the naked oat cultivars compared to the husked oat cultivars was mainly due to the diluting effect of the husk on grain N concentration in the husked oat cultivars.

In this study, the same seed rate was used for both husked and naked oat cultivars. Germination of naked oat cultivars can be lower than that of husked oat cultivars due to the absence of the protective husks (Valentine and Hale, 1990), indicating that in practice, naked oat cultivars may have to be planted at a higher seed rate compared to husked oat cultivars in order to achieve a given plant population. Germination in naked oats can be adversely affected by damage during threshing, due to the lack of husks to protect the kernel, and this damage is greater when the crop was harvested at higher moisture contents (Valentine 1995; Peltonen-Sainio *et al.*, 2001). Therefore, particularly under Irish conditions where rainfall is often common during the harvesting period, particular care would need to be taken when harvesting a naked oat crop that is destined for use as a seed.

Conclusions

Under Irish conditions, naked oats have the potential to produce kernel yields that are similar to or higher than that of husked oats, irrespective of whether they are autumn sown or spring sown. The grain quality of naked oat cultivars, measured in terms of hectolitre weight and grain N concentration, is higher than that of husked oats. Therefore, while more knowledge of its agronomy is required before its widespread cultivation, naked oats is a potentially useful crop under Irish conditions.

Acknowledgements

The assistance of Peter Tiernan, Pat Prior and Ivan Mitchell in field and laboratory tasks associated with this study is gratefully acknowledged.

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