Original article

Effects of soil type and fertilization on yield, chemical parameters, sensory quality and consumer preference of swede (*Brassica napus* L. ssp. *rapifera*).

Short running title: Soil type and fertilizer affect swede quality

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Swede is known as a healthy vegetable with a high content of vitamin C. However, very few studies have worked with the aim to evaluate how varieties, soil type and fertilizer interact and affect quality in swede. In the present study two varieties of swedes (‘Vige’ and ‘Vigod’) were grown on peat, loam and sand, with three levels of K (0, 120, 240 kg ha^{-1}) and N fertilizer (0, 80, 160 kg ha^{-1}). Low to moderate levels of N gave highest saleable yield, highest content of vitamin C and lowest content of nitrate. Peat soil gave highest saleable yield, lowest soluble solids and vitamin C and highest nitrate content. Soluble solids and vitamin C were negatively correlated with total root yield. Sandy soil gave lowest saleable yield, sweetest taste and lowest nitrate content. Contents of total, aliphatic, indole and individual glucosinolates, on dry matter basis, were highest on peat. N fertilization increased the content of most glucosinolates, whereas K affected glucobrassicin at the highest N level. Progoitrin was lowest in roots grown on sand, and was affected by N level and variety on sand and loam soils. Consumers preferred ‘Vigod’, which had the highest intensity of sweetness, although ‘Vige’ had more vitamin C and less nitrate. ~~Consumers consider swedes tasty, cheap and healthy, and prefer to buy them whole but washed.~~

Key words. Vitamin C, glucosinolates, nitrogen, cultivars, sensory profiling, consumer study.

Significance of this study

What is already known on this subject?

Previous studies have shown that there are sensory differences between swede varieties grown, but possible effects of soil type and fertilization have been little studied in this crop.

What are the new findings?

Several relations, as well as interactions, between variety, fertilizer, here N and K, and soil type on one hand and yield, sensory quality attributes, contents of nitrate, vitamin C and glucosinolates on the other hand are new and important findings both for the producer and consumer. We found that consumers preferred the sweetest tasting variety.

What is the expected impact on horticulture?

Knowledge into the factors affecting yield and quality of swede. How to achieve a product that is healthy and liked by the consumer.

Introduction

Besides its importance for fodder, the swede (*Brassica napus* L. ssp. *rapifera*) is a popular vegetable for human consumption in Norway. It is often called the 'Orange of the North', because of its high content of vitamin C. Its uses range from eating raw as a snack, through inclusion in diced vegetable mixtures to the traditional mash accompaniment to smoked lamb at Christmas. In Norway, it is grown on ca. 10% of the area used for field vegetables. Smooth, globe-shaped roots with yellow flesh and purple-coloured skin are preferred, and they should be free from splitting, with few side roots and a small taproot. It is known that there are sensory differences between the swede varieties grown (Børtnes pers com.), but possible effects of soil type and fertilization have been little studied in this crop. High nitrogen (N) fertilization is often thought to have negative effects on quality. Dragland (1983) found little effect of N fertilizer on the texture or odour of swede cv. 'Bangholm Ruta', but its sweetness was markedly reduced. In a pot experiment with carrots (*Daucus carota* L.), nitrogen (N) and potassium (K) fertilization were found to affect content of reducing and non-reducing sugars differently (Habben, 1973). A recent study on carrots in Norway revealed effects on several quality traits of both soil type and N and K fertilization, but it was concluded that variety and season had even greater influences (Seljåsen et al., 2011).

The aim of the present study was to follow up the latter study on carrot, in order to assess effects of soil type and N and K fertilization on yield, quality-related chemical parameters, sensory quality and consumer preference in swedes, relative to the effects of variety. A subgoal was to investigate whether there were any relations between the response variables. A one-year field trial was performed on three contrasting soil types at the same geographic location in south-east Norway, with varying rates of N and K fertilizer, using two of the varieties that are most commonly grown in Norway for human consumption.

Materials and methods

Location and climatic conditions

The trial was performed in 2006 on three soil types (sedimentary sand, morainic loam and peat) at former Research Station Kise (60.77° N, 10.81° E, 128 m altitude). The sandy soil contained 70% sand and gravel and 30% silt and clay, the loam contained 15% clay, >35% silt and 45% sand, whilst the peat was highly decomposed, von Post class H8-9 and the rest fraction consisted of silt (von Post 1922). The sandy soil contained about 8% organic matter, and the loam about 5%. Prior to the experiment, the field had been cultivated with carrots for two years and cereals for several years before that. The growing season during the experimental period was characterised as relatively warm and dry, with temperatures 1-2 °C above normal and with 250 mm rainfall from May to September (normal 310 mm). The potential moisture deficit over evaporative demand was 11 mm in May, 29 mm in June and 30 mm in July. All soils were irrigated when considered necessary for the respective soil type.

Soil temperature was logged at 10 cm depth from mid-June onward (Fig. 1a) and soil moisture was measured at 0-40 cm by time domain reflectrometry (TDR) at 10-day intervals from early July (Fig. 1b). The latter values were used as an indication of irrigation need. The measurements showed that the peat soil was consistently moister and cooler than the other two soils, whilst there was little difference between the latter. This reflects the very high moisture-holding capacity of the peat soil.

Fig. 1.

Plant material

Two varieties of swede were tested in the trial, cvs. ‘Vige’ and ‘Vigod’. These varieties were originally developed at Bioforsk Kvithamar in Central Norway. ‘Vigod’ is considered to represent an improved version of ‘Vige’ and to be more even in size and shape. In the consumer test, an Icelandic variety was included for comparison. This variety was grown on peat soil only with one level of fertilization (80 kg N ha^{-1} and 120 kg K ha^{-1}).

Experimental design

The experiment had a randomised split-split-plot design, with three replication blocks on each soil type. Within each block the varieties were grown on two main plots (4.5 x 12 m), with three K fertilizer levels (0, 120 and 240 kg K ha^{-1}) on subplots (1.5 x 12 m) and three N fertilizer levels (0, 80 and 160 kg N ha^{-1}) on sub-subplots (1.5 x 4 m). Total yield of leaves and roots on plot basis were determined and grading of roots, was performed on all plants. A subset of 30 samples from each soil type, in total 90 samples, each consisting of 10 good quality 0.5-1 kg roots per plot, were subjected to descriptive sensory analysis and analysed for contents of dry matter, nitrate, soluble solids, vitamin C and glucosinolates. The subset used for vitamin C and glucosinolate analyses excluded plots with the intermediate K level (120 kg ha^{-}1) at zero and high N levels (0 and 160 kg ha^{-1}) and those with zero or high levels of K (0 and 240 kg ha^{-}1) at the intermediate N level (80 kg ha^{-1}).

Soil nutrient status

Topsoil samples were taken before fertilization in May 2006, to assess nutrient status. As the experimental sites had been used for K and N fertilizer trials with carrots in previous years, samples were taken on all nine K plots in each trial. The subplot and sub-subplot treatments in the present experiment were matched the treatments applied in the previous experiment. It was considered that there was little or no residual effect of the differences in previous N fertilization, as considerable N leaching takes place each winter in this region. There were clear differences between soil types in soil reaction (pH) and ammonium lactate extractable (plant-available) P (phosphorus) and K (Table 1). The sand soil was more acidic than the other two soils, and the peat had the highest calcium reserve. P availability was very high in the sand, high in the loam and moderate in the peat, whilst K availability was moderately high in sand and loam soils and low in the peat. The K availability was significantly affected by previous fertilization: in loam and sand it was ca. 70% higher on the high K plots than on zero K plots, whilst in peat the difference was ca. 35%.

Table 1.

Crop management

K was given as potassium sulphate (K_2SO_4, 41% K) and N as calcium nitrate ($Ca(NO_3)_2$, 15.5% N). P was applied to all plots as superphosphate ($Ca(H_2PO_4)_2$, 8% P) at a rate of 4.5 kg P ha^{-1} and boron (B) as ($BCa(NO_3)_3$) at a rate of 2 kg B ha^{-1}. All fertilizer was incorporated into the top 5-10 cm of soil before sowing, except in the case of the highest N treatment, where one third was surface applied in mid-July. The swedes were sown in mid-May, spaced at 5 cm and later thinned to 20 cm, in three rows per 1.5 m bed. In all three trials, weed control was performed by spraying with herbicide (Propachlor / Ramrod, producer Monsanto Limited) followed by hand-hoeing as required and pest control was performed by spraying with synthetic pyrethroid (Alfacypametrin / Fastac 50, producer BASF AGRO BV). Manuel harvesting took place on 20th – 26th September.

Sample preparation

Leaves and taproots (called "roots") were separated immediately after harvest, loose soil was removed from the roots that were weighed and analysed as described below. The subset of 90 root samples was stored at 2 °C in polyethylene-lined boxes and size-graded after 4 weeks. Prior to analysing for nitrate and soluble solid roots were washed and frozen at NIBIO. Samples for descriptive sensory analysis and chemical analyses were stored at Nofima at 2 °C. In the period November 13-22nd, descriptive sensory analysis and sampling for chemical analyses were performed. Randomized subsamples were manually peeled and cut into 10 mm cubes by a vegetable dicing machine (Eillert Bl1000A, Machinefabriek Eillert B.V., Ulft, The Netherlands). The cubes were mixed thoroughly and stored overnight, in a thin layer, in open polyethylene bags at 2 °C in darkness prior to analyses. Cubes for sensory analysis were analysed from raw, while cubes for chemical analysis were frozen in liquid nitrogen, milled frozen in a food processor and stored vacuum packed in plastic bags at -80 °C.

Root grading

Total fresh matter yields of roots and leaves were recorded, and roots were graded as saleable or unsaleable (Norsk Standard, 1999). The latter group included numbers and weights of split roots, roots with rotting or clubroot (*Plasmodiophora brassicae*), roots with insect damage by cabbage root fly larvae (*Delia radicum* L. and *Delia floralis* L.) and small (<0.5 kg) roots. Saleable roots were graded as small (0.5-1 kg), medium (1-2 kg) and large (>2 kg).

Dry matter, nitrate and soluble solids in roots

Dry matter content was determined by drying samples at 80 °C for 48 hours. For nitrate analysis, 20 g of milled roots was boiled with 100 mL 0.01 M $CuSO_4$ in a water bath for 1 h. The samples were analysed for nitrate by spectrophotometer (Aquatech international Inc. Irvine California, USA). The soluble solids content was measured in the juice of the milled sample as °Brix (g 100 g^{-1} juice) using an electronic refractometer (Atago-PR-1, Atago CO LTD, Tokyo, Japan). Calibration was performed with distilled water.

Vitamin C

L-ascorbic acid (AA) and L-dehydroascorbic acid (DHA) were analysed according to Rybarczyk-Plonska et al. (2014) with some modifications. Milled, frozen sample (5 g) in duplicate, was added to 20 mL ice-cold 6% *meta*-phosphoric acid - 2 mM EDTA, and immediately homogenised for 30 s at 29 000 rpm (Polytron PT 3100, Kinematica AG, Luzern, Switzerland). The homogenate was filtered at 4 °C through a folded cellulose filter (No. 597½, Schleicher and Schüll, Dassel, Germany), and then through a 0.45 µm Millex-HV filter with PVDF membrane (Millipore). HPLC analysis was performed on the extract as described (Rybarczyk-Plonska et al. 2014). AA was detected at 264 ± 4 nm and quantified with the use of L-ascorbic acid as external standard. The concentration of DHA was calculated as the difference between AA content in reduced and non-reduced extract. The contents of AA, DHA and vitamin C are expressed as mg kg^{-1} fresh matter.

Glucosinolates

Intact glucosinolates were analysed according to Volden et al. (2008). About 200 mg of freeze-dried sample was extracted in 70% (v/v) methanol (73 °C) with glucotropaeolin (0.1 mg, AppliChem GmbH, Germany) as internal standard. Glucosinolates were characterized and quantified as native substances by mass spectrometry and HPLC analysis as described (Volden et al. 2008). Quantification was performed using calibration curves of the standards sinigrin, glucoraphanin and glucotropaeolin based on peak height. Glucosinolates lacking standard were quantified by calibration curves for sinigrin (progoitrin, epiprogoitrin, gluconasturtiin), glucoraphanin (glucoalyssin, glucoerucin, glucoberteroin) or glucotropaeolin (indole glucosinolates). The content of glucosinolates is expressed as mmol kg^{-1} dry matter. The quantification limit was 0.08 mmol kg^{-1} dry matter.

Sensory descriptive analysis

To describe the objective perception of the various root samples, a trained sensory panel performed a descriptive analysis. The panel consisted of 10 subjects employed exclusively to work as sensory assessors at Nofima AS. The panellists have been selected and trained according to recommendations in ISO 8586 (2012). The sensory laboratory has been designed with separate booths and electronic data registration (CSA, Compusence Five, Version 3.80, Canada, 1999). The assessors developed a list of 24 sensory attributes related to appearance, odour, flavour and texture of raw cubes (Table 2). Data were recorded on a 15 cm non-structured continuous scale with the left side of the scale corresponding to the lowest intensity and the right side corresponding to the highest intensity. The computer transformed the responses into numbers between 1.0 (low intensity) and 9.0 (high intensity).

Table 2.

Prior to analysis the panellists were calibrated with two of the extreme swede samples for the purpose to agree on the variation in attribute intensity. In the trial, 25 g of swede cubes from each sample was served in duplicate on coded plates at room temperature to each panellist. The samples were served randomised according to sample (variety, soil, fertilisation), assessor and replicate.

Consumer preference study

Following the sensory analyses, five samples of raw swede with different sensory results were selected (‘Vige’-Peat-K0-N0, ‘Vige’-Peat-K120-N80, ‘Vigod’-Loam-K0-N160, ‘Vigod’-Sand- K120-N80 and Icelandic variety-Peat – K120 – N80) for a preference test performed by 115 consumers. The consumers ranged between 20 and 65 years of age, including both men and women. They were all favourably disposed towards swede in advance, but their occupations were not related to vegetable production. Each consumer tasted three to four slices of raw swede (approximately 5 cm^3) of each sample and indicated their liking of them on a scale from 1-9, where 9 was most positive. Following this, the consumers were presented with 23 statements on swede, to each of which they gave an agreement score on a Likert scale. The questionnaire contained questions about gender, age and eating frequency of swede and statements on general usage of swede, sample preparation before eating, snack or regular meal, preference for root size when bought, price, and product information from the sales person.

Statistical analyses

Minitab 15 procedure Balanced ANOVA was used for analysis of variance of the yield as well as dry matter and nitrate concentrations, with a separate analysis for each soil. A split-split-plot model was used, as described above (main effects of variety, split-plot effects of K level and split-split-plot effects of N level). Significance levels are indicated by *** = $p<0.001$, ** = $p<0.01$, * = $p<0.05$, ns = $p\geq0.05$.

In the case of data for vitamin C and glucosinolates, ANOVA was performed in Minitab using the data for zero and high levels of N and K fertilizer, in order to obtain a balanced model. Differences between soil types and cultivar were tested using all 90 values. ANOVA of the sensory and preference analyses was performed in SAS 9.2 for Windows (SAS Institute Inc., Cary, NC, USA), using an unbalanced design, including soil type and fertilizer treatments. Tukey's multiple comparisons test of significance at p=0.05 was used to evaluate differences between these groupings. Pearson product-moment correlation was applied analysing the relationship between root content of soluble solid and root yield and root dry matter content respectively.

PCA (Principal Component Analysis) was performed using The Unscrambler® X, Version 10.2 (CAMO Software, Oslo, Norway). The variables were weighted by dividing them by their standard deviations.

Results

Effects on yields and root grading

The final plant number was highest on loam soil (11.1 m^{-2}), slightly lower on sand (10.4 m^{-2}) and lowest on peat (8.5 m^{-2}). It appeared to decline by about 5 % with increasing N fertilizer on all soils, but this effect was not statistically significant. On loam soil the total root yield of 'Vige' was 10% higher than that of 'Vigod' (p<0.05), but there was no significant difference on other soils. K fertilization had no effect on total yield on loam and sand, but zero application reduced it by 10% on peat soil (p<0.05). The effect of N fertilization on yield was highly significant on all soils (Table 2). The greatest effect was seen on sand, where it more than doubled total yield. On loam it increased it by 70%, but on peat soil the increase was only 20%. At the highest N level, the total yield was roughly equal on all soils. Leaf weights increased similarly, and were greatest on the peat soil. Significant interactions between variety and N-level on loam and peat soils (p<0.001) indicated a greater effect of N on leaf weight in 'Vigod' than in 'Vige'.

Table 2.

The saleable root yields were also strongly affected by N fertilizer, and showed on all soils a decline at the highest N level relative to the use of 80 kg N ha^{-1} (Table 2). The saleable yield was one third of total yield on sand, about half of total yield on loam and two thirds on peat. A significant N x variety interaction on loam (p<0.05) indicated that saleable yield of 'Vigod' declined more than that of 'Vige' at the highest N level. 'Vigod' had greater saleable yield than 'Vige' on all soils, with greatest difference (17%) on peat and least on loam (6%). K fertilizer had no overall effect on saleable yield. The loss of saleable yield due to rotting or clubroot was marginal on all soils, and that due to splitting was relatively low except at the highest N level on loam soil (Fig. 2a). Insect damage occurred on all soils, but caused the greatest losses on sand. Losses due to small root size were high on both loam and sand, especially in the absence of N fertilizer, but were relatively low on peat. There was more splitting in 'Vigod' than in 'Vige', significantly so (p<0.05) on loam and peat soil. Other loss categories differed little between varieties. K fertilization increased the weight and proportion of split roots on both loam and peat (p<0.05), but had no other significant effect on losses of saleable yield.

The percentage size grading of saleable roots in relation to soil type and N fertilizer level is shown in Fig.2b. At the zero N level, almost all roots were < 1 kg on loam and sand, but about half were >1 kg on peat. At 80 kg N ha^{-1}, about 30% were >1 kg on loam and sand, increasing to about 50% at 160 kg N ha^{-1}. At the highest N level peat soil had about 10% of roots >2 kg.

Fig. 2a and b

Effects on contents of dry matter, nitrate and soluble solids in roots

Root dry matter content was reduced significantly by N fertilization on loam and sand, where it was ca. 2% units higher on zero N plots than on plots with N fertilizer (Table 2). This effect was much smaller on peat soil. Root dry matter was lowest in swedes grown on peat and highest on sand.

The content of soluble solids in roots was lower with N fertilizer than without on sand and loam, whilst roots grown on peat had the lowest soluble solid content irrespective of N level (Table 4). The soluble solids values were closely correlated with root dry matter content (°Brix = 4.12 + 0.43 * dry matter %, r^2=0.64, n=162, p<0,001) and appeared to be governed by the total yield level ((SSC = 10,4- 0,039*yield, r^2=0.50, n=162, p = <0,001). 'Vige' had on all soils significantly higher content of soluble solids than did 'Vigod', by on average 0.5 °Brix, with the greatest difference on sand (0.7 °Brix, p<0.01) and least on peat (0.3 °Brix, p<0.05). K fertilization had no significant effect on soluble solids content (data not shown).

Table 4.

Nitrate content in roots increased markedly on all soils at the highest N level (Table 4). It was considerably higher on peat soil than on the other soils, even without N fertilization. On loam soil the nitrate content was somewhat higher in 'Vigod' than in 'Vige' (p<0.05), by on average 20 mg kg^{-1} fresh matter, but an opposite trend was seen on the other soils (data not shown). K fertilization had no significant effect on nitrate content (data not shown).

Effects on vitamin C content in roots

Cultivar, soil type and fertilization had significant effects on the vitamin C content in swede roots, as well as on its components AA and DHA (Table 5). 'Vige' had significantly higher content of AA and vitamin C than did 'Vigod', and the cultivar difference for vitamin C was ca. 30 mg kg^{-1} on sand and peat and 10 mg kg^{-1} on loam (data not shown). The vitamin C content differed significantly between swedes grown on sand, loam and peat, with the lowest level on peat (Table 5). Relative to the zero N treatment, the highest level of N fertilizer reduced the content of vitamin C on all three soils, significantly so on sand and peat. The effect of K fertilization, on the other hand, was positive in all cases except at the zero N level on sand. These differences in vitamin C content between fertilizer treatments were of the same order of magnitude as those found between varieties. Vitamin C was correlated negatively with total root yield (r=-0.36, p<0.001) and positively with root dry matter content (r=0.31, p<0.01).

Table 5.

Effects on glucosinolate contents in roots

Using an analytical method for native glucosinolates, 13 glucosinolates were detected and 11 of them could be quantified (Table 6). Glucoraphanin was detected but it was below the quantification limit. Gluconapoleiferin had a content of maximum 0.5 mmol kg^{-1} dry matter but it was excluded, since the HPLC peak was not clean. Glucoberteroin and gluconasturtiin were well separated by HPLC and could be quantified individually. On a molar basis, 77-82% of the total quantified glucosinolates were aliphatic. Progoitrin had the highest content with a share of 51-62%. Glucoberteroin was next most abundant (12-15%) followed by 4-OH-glucobrassicin, neoglucobrassicin and glucoerucin (5-7%), and glucoalyssin, glucobrassicin and 4-MeOH-glucobrassicin (~3%). The lowest contents were found for gluconasturtiin, sinigrin and epiprogoitrin, i.e. 0.5-2.5%.

There were significant effects of cultivar, soil type and fertilization on the content of total glucosinolates and most of the individual glucosinolates in the swede roots (Table 6). 'Vige' had highest content of total glucosinolates (by 10%) and of total aliphatic glucosinolates, while the level of total indole glucosinolates was similar in the two cultivars. For individual glucosinolates, 'Vige' had the highest contents of progoitrin, sinigrin, epiprogoitrin, glucobrassicin and 4-OH-glucobrassicin, and 'Vigod' the highest contents of glucoberteroin, 4-MeOH-glucobrassicin and neoglucobrassicin. The largest difference was for progoitrin by 1.74 mmol kg^{-1} (18%). Swedes grown in peat soil had all over the highest content of individual - and total glucosinolates (12% and 28% higher than loam and sandy soils, respectively (Table 6). Swedes from sand soil had significantly lower contents than swedes from peat soil for all glucosinolates, except for neoglucobrassin, the only glucosinolates with similar level in all soils. Only progoitrin, glucoerucin and neoglucobrassicin had similar levels in swedes grown in peat and loam soil. Swede roots from loam and sandy soils were more similar in their glucosinolate profiles. Some glucosinolates had, however, lower content in sandy soil, i.e. progoitrin, epiprogoitrin, glucoberteroin and 4-MeOH-glucobrassicin. Fertilization had a significant effect, where the highest N-level (160 kg ha^{-1}) produced swedes with 29%, 23% and 69% higher contents of total, aliphatic and indole glucosinolates, respectively, than the lowest N-level with 0 kg ha^{-1} (Table 6). Only glucoerucin and gluconasturtiin were insensitive to N fertilization. Although progoitrin increased 10% upon N-fertilization, there were one- to twofold increases for sinigrin, epiprogoitrin, glucoberteroin and glucobrassicin. Fertilization with K had no effect, except for glucobrassicin at the highest level of N. Within the soil types loam and sand, nitrogen fertilization and variety also had a significant influence on the content (p=0,05).

Table 6.

Effects on sensory quality of raw swede cubes

There were significant differences between the two varieties in 14 of the 24 sensory attributes tested, but the effects of soil type were less marked, with significant differences in only seven attributes (Table 7). 'Vigod' had a higher intensity of whiteness and was more yellow in colour than 'Vige', and many of its flavour attributes were less intense than those of 'Vige'. 'Vigod' had less intense bitter, stinging, and sulphurous flavour, and lower intensity of astringency and aftertaste. 'Vige' was somewhat harder and crispier, but less juicy than 'Vigod'.

Table 7.

Swedes grown on peat had a higher intensity of soil odour than those grown on the other soils (Table 7). Swedes grown on peat soil were significantly more bitter, pungent and astringent than the swedes grown on sand, whereas swedes from loam soil had intermediate intensities of these attributes with non-significant differences to the other soil types. Peat soil gave a juiciness significantly higher than that of loam with intermediate juiciness in swedes from sand soil. Sweet taste was most intense in samples from sand and least intense in peat-grown samples.

Fertilizer treatment also had significant effects on 14 of the 24 sensory attributes, but not always on the same traits as those that differed between varieties. Effects of N fertilizer level clearly dominated, whilst those of K fertilizer were much smaller and often non-significant and/or inconsistent between high and low N levels. For the sake of clarity, therefore, only the N level means are tabulated in Table 7. Increasing N fertilizer gave paler roots with more yellow tone and less colour intensity. Its only effect on odour was that it gave a more intense sensation of soil odour. Many taste and flavour attributes increased in intensity with increasing N fertilizer level. Overall flavour was more intense, as was also bitter taste, soil flavour, pungent flavour, sulphurous flavour, as well as astringency and aftertaste. Acidic taste and sweet taste both decreased markedly with increasing N fertilizer.

Effects on consumer preference

Consumers preferred the variety 'Vigod' cultivated on sandy soil and fertilized with 120 kg K and 80 kg N ha^{-1}, and there was no statistical difference in preference between the remaining three samples of 'Vige' and 'Vigod' tested (Table 8). However, the Icelandic cultivar had significantly lower preference than the other cultivars. There was no effect of gender or age in the sample ranking. The consumers who preferred the 'Vigod' cultivated on sandy soil were the consumers reporting the highest personal consumption of swede. Scores for the 23 presented statements showed highest consumer agreement with the following statements: Swedes are 'eaten because they are good', 'eaten for dinner', 'non-fattening', 'not a boring vegetable', 'not desirable for purchase when cut into pieces', 'not used in wok-food', 'cheap', 'store well', 'preferably bought washed'. They also agreed that 'shop employees have little knowledge about swede quality'.

Table 8.

Correlation between measured parameters

Principal component analysis of sensory attributes and chemical parameters gave a clear separation of the two cultivars by PC-2 and of the highest and lowest nitrogen fertilization by PC-1 (Fig. 3a). There was also an effect of soil type: within each fertilization level, root samples from peat soil are placed to the right of the samples from sand and loam soils. Correlation loadings (Fig. 3b) show to the right in the chart that several sensory attributes, such as soil flavour, bitter taste, sulphurous flavour, aftertaste, astringency and pungent flavour, are placed close together and therefore correlate positively with several chemical parameters, such as total glucosinolates, all indole glucosinolates and all but one of the aliphatic glucosinolates. Parameters outside the inner ellipse and placed close to each other are significantly correlated to each other. Situated to the left in the chart are sweet taste and acidic flavour and they are thus negatively correlated with most of the glucosinolates to the far right. In-between, but on the left side, are colour hue and colour intensity, which are to some extent correlated with vitamin C and ascorbic acid in the vicinity. Projecting correlation loadings on top of the score plot, demonstrates the relation between swede roots and their properties: the samples to the right were grown with the highest level of N-fertilization and the ones to the left with the lowest level (Fig. 3a, b).

Fig. 3a and b.

Discussion

Yields and root grading

Cutcliff and Sanderson (1989) reported similar increases in swede yield with increased N fertilization from Canada, but they reported little or no effect of K on yield. Seljåsen et al. (2012) also found this for carrots in Norway. As in our study, peat soils are often deficient in K, which may account for the reduced yield we found with zero K-application on this soil. On the other hand, peat soils have high N reserves, as reflected here by the low response to N fertilizer that we found. A similar finding was reported for swedes grown on peat soil by Ekeberg (1986), who also found a yield increase of only 20% between 0 and 80 kg N ha^{-1}. For swedes grown on mineral soils, Dragland (1983) found no increase in total yield beyond 160 kg N ha^{-1}, whilst for saleable yield optimum N fertilization was only 80 kg ha^{-1}, due to increases in splitting and excessive root size at higher N levels. A similar result was reported by Nes (1987), who found the saleable yield of swedes to increase by only 2 % between 100 and 140 kg N ha^{-1}. Saleable yield is obviously more important than total yield in economic terms, but it is also important for environmental reasons. When N fertilization to swedes was increased from 110 to 160 kg ha^{-1}, Riley and Berentsen (2000) found that N uptake in roots increased by only 12 kg ha^{-1}, whilst that in leaves increased by 19 kg ha^{-1}. Some of the residual N may contribute to succeeding crops (Riley, 2002), but much of it may be lost by leaching or denitrification.

The lower root dry matter in roots grown on peat soil and its decline with increasing N fertilization corresponds with the lower specific gravity that was found with increasing N fertilizer by Cutcliff and Sanderson (1989). Nevertheless, despite low content on peat, the average dry matter yield was still highest on this soil. On all soil types, dry matter yield was highest at 80 kg N ha^{-1}. The declines in root dry matter content reported here on mineral soils (about 2 % units between 0 and 160 kg N ha^{-1}) were similar to those reported by Dragland pers. com.

The reason for the differences between soils in plant number is not clear. The peat soil had in general lower temperatures and higher moisture contents than the other soils, which may account for lower germination there. However, the lower plant density on peat soil was not reflected in either total or saleable yield. The increased proportion of roots > 2 kg at the highest level of N fertilization on peat soil may have been related to lower plant density. This is a disadvantage, as this size class is in excess of that recommended by Norwegian Standards. On the other hand, fewer roots were discarded for other reasons on peat than on loam and sand, where more factors seemed to influence the saleable yield, including variety.

The effects of soil type may be expected to vary between years, as observed in the study by Seljåsen et al. (2012). The growing season in 2006 was warm and dry which may account for some of the differences in yield that we found between the soil types. Despite irrigation, the sand and loam soils had lower moisture content than peat. Nevertheless, much of this difference probably consisted of water that was unavailable to plants. This suggests that roughly equal moisture availability to the crop was maintained on all soils. The higher insect damage found on sand may nevertheless have been caused by drought stress at certain periods on this soil. In trials in which drought stress was imposed at different stages of growth, Dragland (1982) found that of up to 27 % of roots were unsaleable due to cabbage root fly damage after drought, compared to only 8% in the absence of drought. He also found somewhat more splitting after drought, and considerably higher percentages of small roots (<0.5 kg), as was the case at low N levels on both mineral soils in our trials. This suggests that, despite irrigation, the moisture supply may not always have been adequate on these soils.

Effects on content of chemical compounds

High content of nitrate is considered undesirable in food produce. The content we found in swedes was generally low, and the increases we found with increasing level of N fertilization correspond with the findings of Dragland (1983) in swedes and Seljåsen et al. (2012) in carrots. Even the high nitrate content that we found in swedes grown on peat soil is unlikely to result in intake in excess of the acceptable daily intake in vegetables (3.7 mg kg^{-1} body weight) recommended by FAO/WHO (2002). This is in accordance with the conclusion of the European Food Safety Authority (2008), that a vegetable intake of 400 g fresh matter per day presents little risk from nitrate poisoning.

It is important to focus on the vitamin C content in swedes, as their status as the “Orange of the North” means that consumers expect them to be a good source of vitamin C (Vittersø et al., 2005). The negative correlations of both soluble solids and vitamin C content with total yield, and the tendency for these properties to be affected negatively by N fertilization, are justifiable causes for concern. Avoidance of excessive N supply is essential. The differences between varieties are also of importance. Whilst ‘Vigod’ gave higher yield than 'Vige', it unfortunately had lower content of soluble solids and vitamin C and a higher nitrate level.

Since individual glucosinolates and their degradation products differ widely in sensory properties and in the type of bioactivity they can have in the human body after ingestion, various effects on the glucosinolate profile is important to document. The results of the present study indicate that cultivar, soil type and N fertilizer level had different effects on various glucosinolates. Results on glucoberteroin in swedes have also been obtained in the present study. This glucosinolate has probably not been identified correctly in some earlier studies. Information on sensory properties of glucoberteroin is scarce (Harborn et al., 1999). In several studies, using a method with desulphation of glucosinolates before HPLC, glucoberteroin was probably quantified as gluconasturtiin or vice versa (discussed by Johansen et al., 2016).

Relations between sensory quality and chemical properties

The PCA analysis showed clear correlation between sensory scores, compound contents and treatments. That sweet taste was more intense in samples grown on sand soil is in agreement with the high soluble solids contents on this soil compared with the other soils. In addition, the sweetest taste and the highest content of soluble solids was found for the lowest N fertilization level. Although 'Vige' had a higher content of soluble solids than 'Vigod', this was not recognised in the sensory analyses on sweetness. On the other hand, the fact that 'Vige' was bitterer than 'Vigod' could be in agreement with higher contents of progoitrin, sinigrin and glucobrassicin, as bitter and sweet compounds are acting in a competitive manner on the sensory apparatus. Progoitrin, being the main glucosinolate in swedes, is degraded to goitrin, which is bitter and blocks the thyroid gland to produce thyroid hormone. However, it is not known whether goitrin or other compounds are responsible for the bitter taste, or part of it, in swedes. Conclusive evidence to explain taste and flavor from contents of chemical constituents in brassicas is largely lacking in the literature (see Johansen et al. (2016) and references therein).

Sensory quality and consumer preference

The trained sensory panel found a decreased acidic taste and sweet taste with increasing level of N fertilizer while sandy soil increased the sweetness of the roots. These findings were reflected in the preference test, where 'Vigod' grown on sand with moderate N fertilization was given the highest preference score. 'Vige' also had higher scores than 'Vigod' in sulphurous flavour, bitter taste and aftertaste, which are not considered desirable attributes according to the results from the consumer test.

Conclusions

K fertilization had little effect on swede yield or quality, but it increased the content of root vitamin C content and increased the glucobrassicin level at the highest N level. In contrast to this low to moderate levels of N fertilizer gave the highest yield of saleable roots, the highest content of vitamin C and the lowest levels of nitrate and glucosinolates. swedes grown on peat gave highest saleable yield, but had somewhat lower content of soluble solids and vitamin C, and higher levels of nitrate'. Measured on a dry weight basis, gave swede grown on peat soil highest content of most glucosinolates was, while calculated on a fresh weight basis there is little difference between soil types. Of the two varieties was cvs. 'Vigod' preferred by the consumers and this variety had highest sweetness and lowest content of progoitrin, although cvs. 'Vige' had higher content of soluble solids and vitamin C, and a lower nitrate level. The consumers were positive to swedes and the sensory quality and preferences appeared to be affected by variety, soil type and the level of N fertilization. ~~In general, Norwegian consumers bought swedes because they were looked upon as a traditional vegetable together with popular dishes and because they are cheap, tasty and healthy. The consumers preferred whole, washed roots.~~

Acknowledgements

The project was funded primarily by the Norwegian Foundation for Research Levy on Agricultural Products (Project no. 162584 and 224892). We wish to thank Dr. Steinar Dragland for initiating the research and Senior Research Technician Erling Berentsen for performing the fieldwork. The contributions of Josefine Skaret and Anne Skivik Jensen at Nofima are gratefully acknowledged, as is that of the sensory panel.

References

Cutcliff, J.A., and Sanderson, J.B. (1989). Effects of added nitrogen and potassium on yield and storability of rutabagas. *Canadian Journal of Plant Science* 69 p.1359-1363.

Dragland, S. (1982). Effects of drought at different growth stages of swedes. *Research in Norwegian Agriculture* 33 p.43-49. (in Norwegian with English summary)

Ekeberg, E. (1986). Fertilizer placement on peat soils. *Research in Norwegian Agriculture* 37 p.23-28. (in Norwegian with English summary)

European Food Safety Authority. (2008). Balancing the consumer risks from nitrate in vegetables with the benefits of a balanced diet high in vegetables and fruit. Press Release 5th June.

FAO/WHO. (2002). Evaluation of certain food additives and contaminants. Fifty-ninth Report of the Joint FAO/WHO Expert Committee on Food Additives (JECFA). WHO *Technical Report Series* No. 913.

Habben, J. (1973). Quality constituents of carrots *Daucus carota* L. as influenced by nitrogen and potassium fertilization. *Acta Horticulturae* 29 p.295-305.

Harborne, J. B., Baxter, H., and Moss, J. P. (1999). *Phytochemical Dictionary: A Handbook of Bioactive Compounds from Plants*. Philadelphia, PA: Taylor and Francis, Inc.

ISO 8586. (2012). General guidance for the selection, training and monitoring of selected assessors and expert sensory assessors.

Johansen, T.J., Hagen, S.F., Bengtsson, G.B., and Mølmann, J.A.B. (2016). Growth temperature affects sensory quality and contents of glucosinolates, vitamin C and sugars in swede roots (*Brassica napus* L. ssp. *rapifera* Metzg.). *Food Chem.* 196 p. 228-235.

Ju, H.Y., Chong, C., Bible, B.B., and Mullin, W. (1980). Seasonal variation in glucosinolate composition of rutabaga and turnip. *Can. J. Plant Sci*. 60 p. 1295-1302.

Norsk Standard (1999). Vegetables. Swede (Rutabaga). Quality, grading, packaging and marking. NS 2833, ICS 67.080.20, 7nd edition, January 1999.

Nes, A. (1987). Nitrogen fertilization and plant density of swedes. *Norwegian Agricultural Research* 2 p.133-140. (in Norwegian with English summary)

Riley, H., and Berentsen, E. (2000). Nitrogen fertilization of vegetables: N-leftover in crop residues and in soil and its fertilizer value for cereals and potatoes grown the following year. *Planteforsk Rapport* 20/2000, 16 pp. (in Norwegian with English summary)

Riley, H. (2002). Nitrogen contribution of various vegetable residues to succeeding barley and potato crops. *Gartenbauwissenschaft* 67 p.17-22.

Rybarczyk-Plonska, A., Hansen, M.K., Wold, A-B., Hagen, S.F., Borge, G.I.A., and Bengtsson, G.B. (2014). Vitamin C in broccoli (*Brassica oleracea* L. var. *italica*) flower buds as affected by postharvest light, UV-B irradiation and temperature. *Postharvest Biology and Technology* 98 p.82–89.

Seljåsen, R., Lea, P., Torp, T., Riley, H., Berentsen, E., Thomsen, M.G., and Bengtsson, G.B. (2012). Effects of genotype, soil type, year and fertilisation on sensory and morphological attributes of carrots (*Daucus carota* L.). *Journal of the Science of Food and Agriculture* 92 p.1072-99.

Tian, Q.G., Rosselot, R.A., and Schwartz, S.J. (2005). Quantitative determination of intact glucosinolates in broccoli, broccoli sprouts, brussels sprouts, and cauliflower by high-performance liquid chromatography-electrospray ionization-tandem mass spectrometry. *Analytical Biochemistry* 343 p.93-99.

Vittersø, G., Rødbotten, M., Olsen, N.V. and Dragland, S. 2005. Carrots and swedes. Consumers' perception and use. *Report from four focus groups* 12/2005, 76 pp. (in Norwegian with English summary)

Volden, J., Borge, G.I.A., Bengtsson, G.B., Hansen, M., Thygesen, I.E., and Wicklund, T. (2008). Effect of thermal treatment on glucosinolates and antioxidant-related parameters in red cabbage (*Brassica oleracea* L. ssp. *capitata* f. *rubra*). *Food Chemistry* 109 p.595-605.

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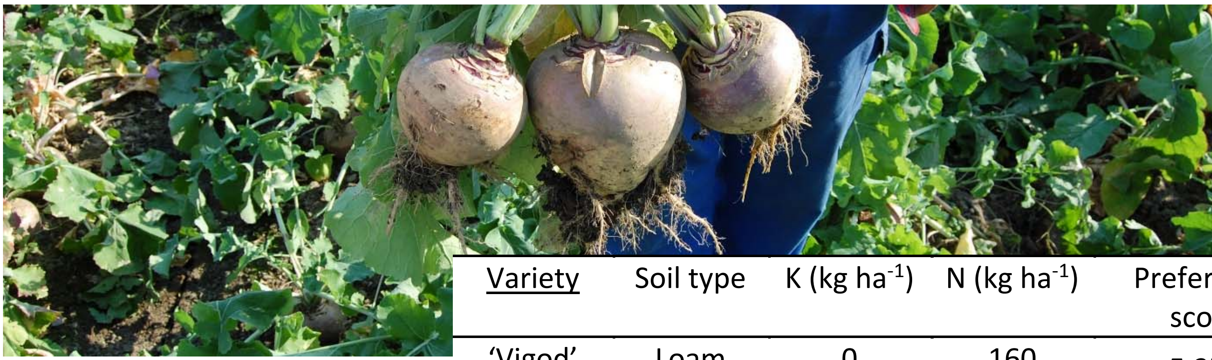


Variety	Soil type	K (kg ha^{-1})	N (kg ha^{-1})	Preference score
'Vigod'	Loam	0	160	5.27^{b}
'Vigod'	Sand	120	80	6.17^{a}
'Vige'	Peat	0	0	5.46^{b}
'Vige'	Peat	120	80	5.15^{b}
Icelandic variety	Peat	120	80	4.03^{c}

Tables and Figures

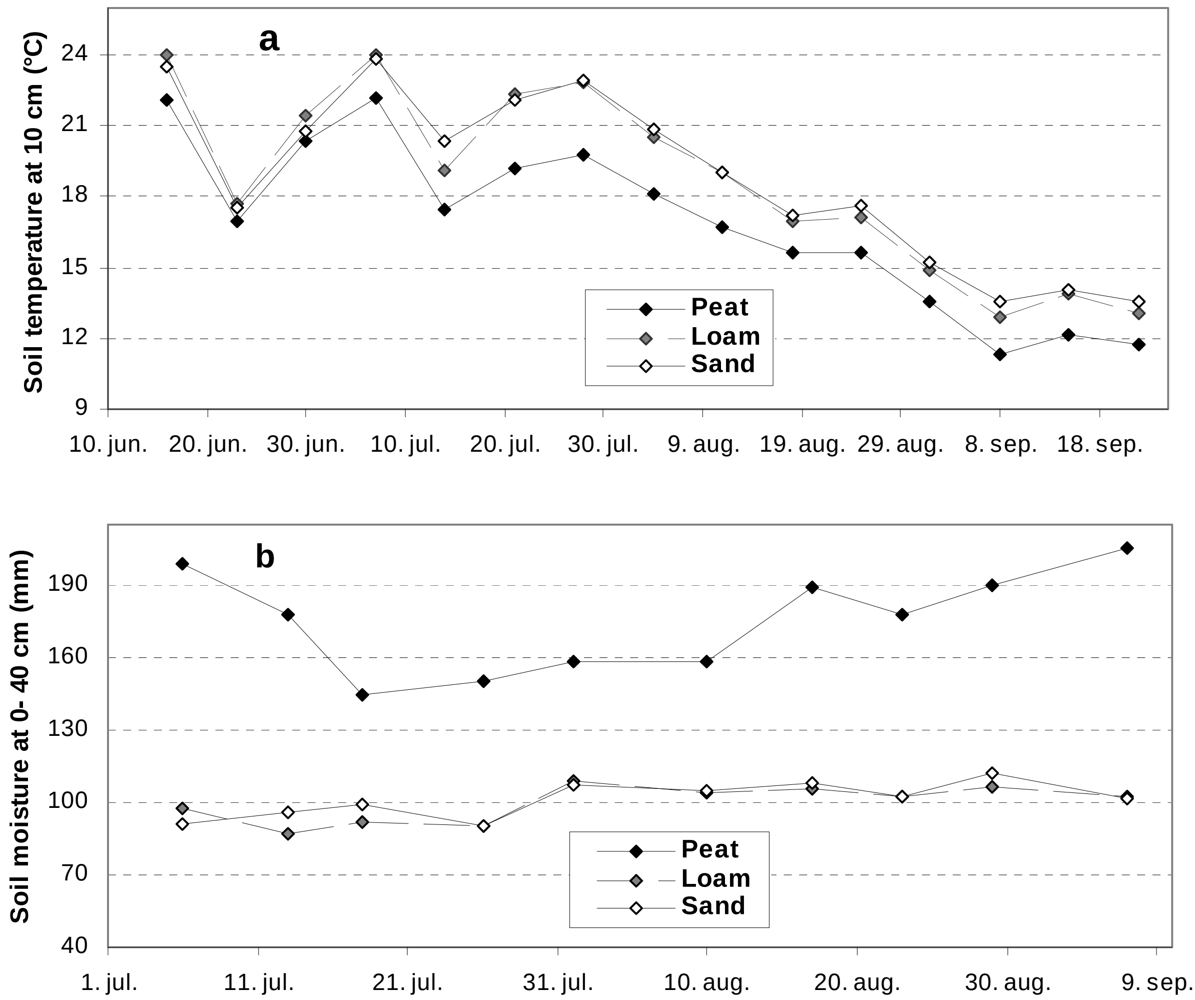
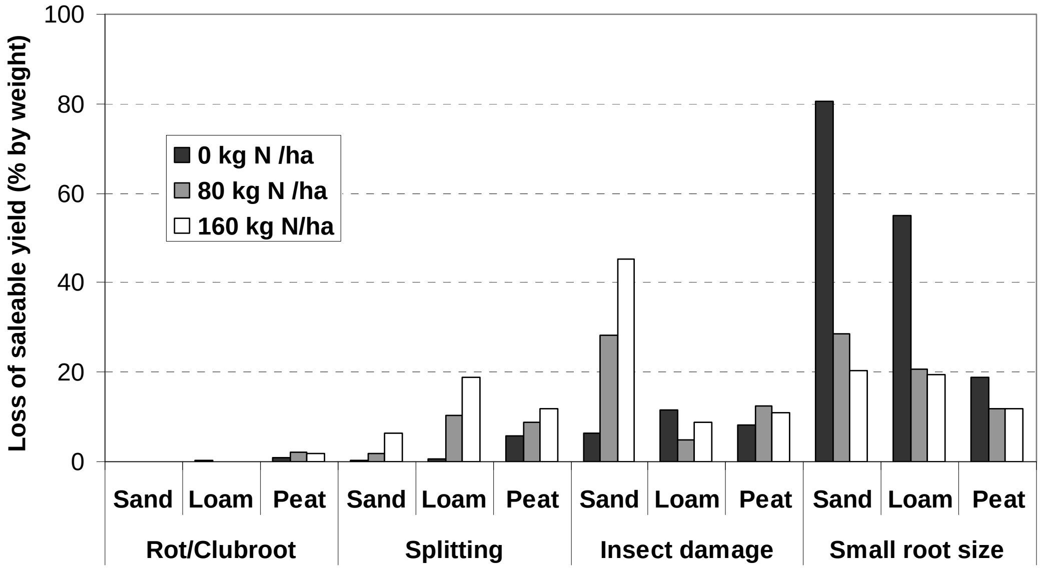


Fig. 1. Mean soil temperature (°C) at 10 cm depth (a) and soil moisture content (mm) at 0-40 cm depth (b), measured in the three trial soils during the growing season of 2006.



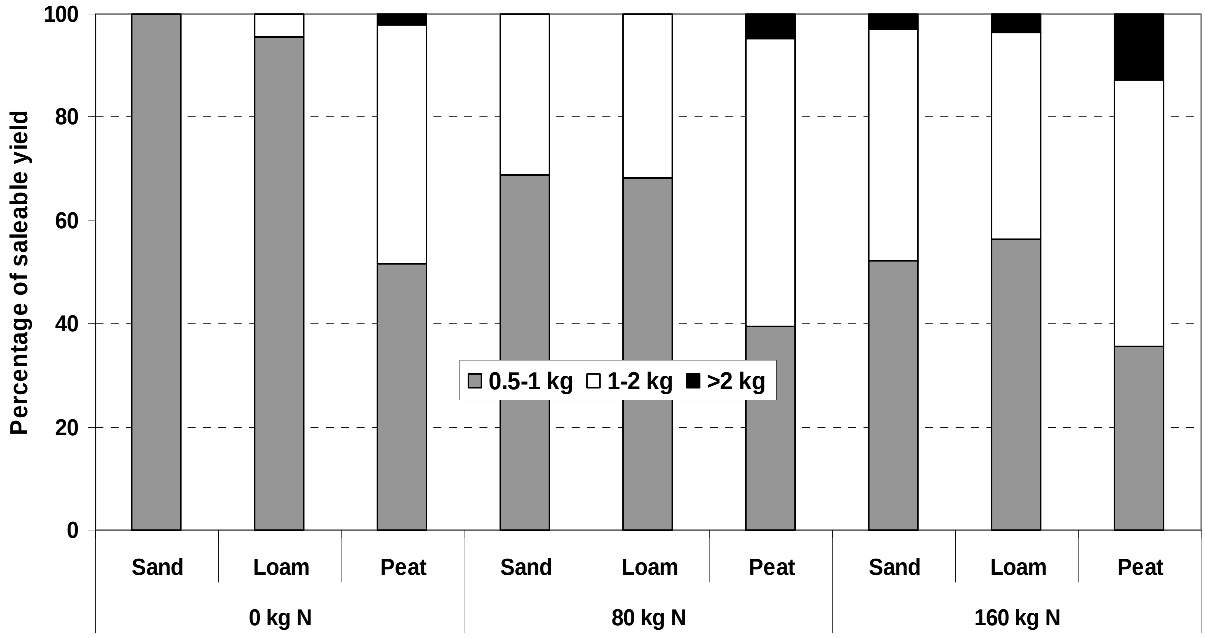


Fig. 2a and b. Loss of saleable yield by various causes and percentage size grading of saleable roots in relation to N fertilizer level and soil type.

(kindly see attached pdf file)

Fig. 3a and b. Principal component analysis and correlation loadings of sensory attributes and chemical parameters of two cultivars of Swede grown on three different soil types at three levels of fertilization with K and N.

Table 1. Soil reaction (pH) and ammonium lactate (AL) extractable nutrients in the trial soils after sampling before fertilization in May 2006 (mg kg^{-1}, mean $\pm$ SD, n = 9)

Soil type	pH in water	P-AL	K-AL	Ca-AL	Mg-AL
Sand	5.4	156	188	1921	91
Loam	5.9	113	182	2544	113
Peat	5.9	79	71	6499	138

Table 2. Attributes in descriptive sensory analysis of raw swede cubes with definitions.

Colour	Colour intensity	Surface colour evaluated according to the NCS-system.
	Colour hue	Surface colour evaluated according to the NCS-system. 1=G80Y (green/yellow), 9=Y30R (yellow/red)
	Whiteness	Surface colour evaluated according to the NCS-system.
Odour	Odour intensity	Intensity of all odours in the sample
	Acidic odour	Fresh, acidic or sweet fruit odour related to organic acids
	Green odour	Odour of green (e.g. fresh, green grass)
	Soil odour	Odour of fresh soil
	Pungent odour	Pungent, burning odour as in radish.
	Sulphurous odour	Odour of sulphur
Flavour and taste	Flavour intensity	Intensity of all flavours in the sample
	Acidic flavour	Fresh, acidic or sweet fruit flavour related to organic acids
	Sweet taste	Related to the basic taste sweetness (sucrose)
	Bitter taste	Related to the basic taste bitter (caffeine)
	Green flavour	Flavour of green (e.g. fresh, green grass)
	Soil flavour	Flavour of fresh soil
	Pungent flavour	Pungent, burning flavour as in radish
	Sulphurous flavour	Flavour of sulphur
	Stale flavour	Cloying, unfresh, sickeningly sweet flavour
	Astringency	A complex feeling, followed by contractions, a feeling of dryness, puckering of the skin or the mucous membranes in the mouth
	Aftertaste	Taste remaining in the oral cavity after 30 seconds
Texture	Firmness	Mechanical attribute related to the force needed to bite through the sample. Assessed by the molars after the first bite
	Crispness	Breaks easily, not viscous
	Juiciness	Perception of water after 4-5 chews
	Fibrousness	Geometric attribute relating to the shape and orientation of the particles in a product

Table 3. Effect of N fertilization on yield and dry matter content of swedes grown on different soils

N (kg ha^{-1})	Sand	Loam	Peat	Sand	Loam	Peat
	Total root yield (Mg fresh matter ha^{-1})			Leaf weight (Mg fresh matter ha^{-1})		
0	24.2	36.2	54.4	4.7	5.1	12.3
80	50.2	60.3	65.5	10.6	10.5	19.2
160	59.1	64.9	64.2	17.9	17.0	25.1
p	***	***	***	***	***	***
	Total saleable yield (Mg fresh matter ha^{-1})			Root dry matter content (%)		
0	3.5	13.3	35.9	12.0	10.8	8.8
80	21.8	38.6	43.1	10.4	9.4	8.4
160	16.9	33.7	40.7	10.2	9.1	8.5
p	***	***	*	***	***	Ns

Table 4. Effect of N fertilization on soluble solids and nitrate contents of swede roots (mean, n= 45).

N (kg ha^{-1})	Sand	Loam	Peat	Sand	Loam	Peat
	Soluble solids (^{o}Brix)			Nitrate (mg kg^{-1} fresh matter)		
0	9.6	8.9	7.8	24	34	100
80	8.6	8.1	7.6	21	34	237
160	8.7	8.2	7.6	68	174	629
p	***	***	ns	***	***	***

Table 5. Effects of cultivar (n=45) , soil type (n=30)and fertilization (N and K, kg ha^{-1}) (n=18) on AA (L-ascorbic acid), DHA (L-dehydroascorbic acid) and vitamin C contents of swedes (mean, mg kg^{-1} fresh matter).

	AA	DHA	Vitamin C
Cultivar			
'Vige'	198	29.5	227
'Vigod'	167	34.8	201
p	***	*	***
Soil type			
Sand	187^{a*}	31.5^{b}	215^{b}
Loam	192^{a}	40.0^{a}	232^{a}
Peat	170^{b}	25.0^{b}	195^{c}
p	***	***	***
Fertilization			
N0 K0	188^{a}	31.5^{ab}	218^{a}
N0 K240	199^{a}	32.7^{ab}	229^{a}
N80 K120	185^{a}	36.8^{a}	222^{a}
N120 K0	161^{b}	24.3^{b}	183^{b}
N160 K240	183^{a}	35.5^{a}	217^{a}
p	***	*	***

*Values of AA, DHA or vitamin C for each treatment with common letters are not significantly different by Tukey's multiple comparisons test.

Table 7. Effects of variety, soil type and N fertilizer on intensity of 24 sensory attributes of swedes. Different suffixed letters in rows denote significant differences between varieties, soil types or fertilizer levels, respectively.

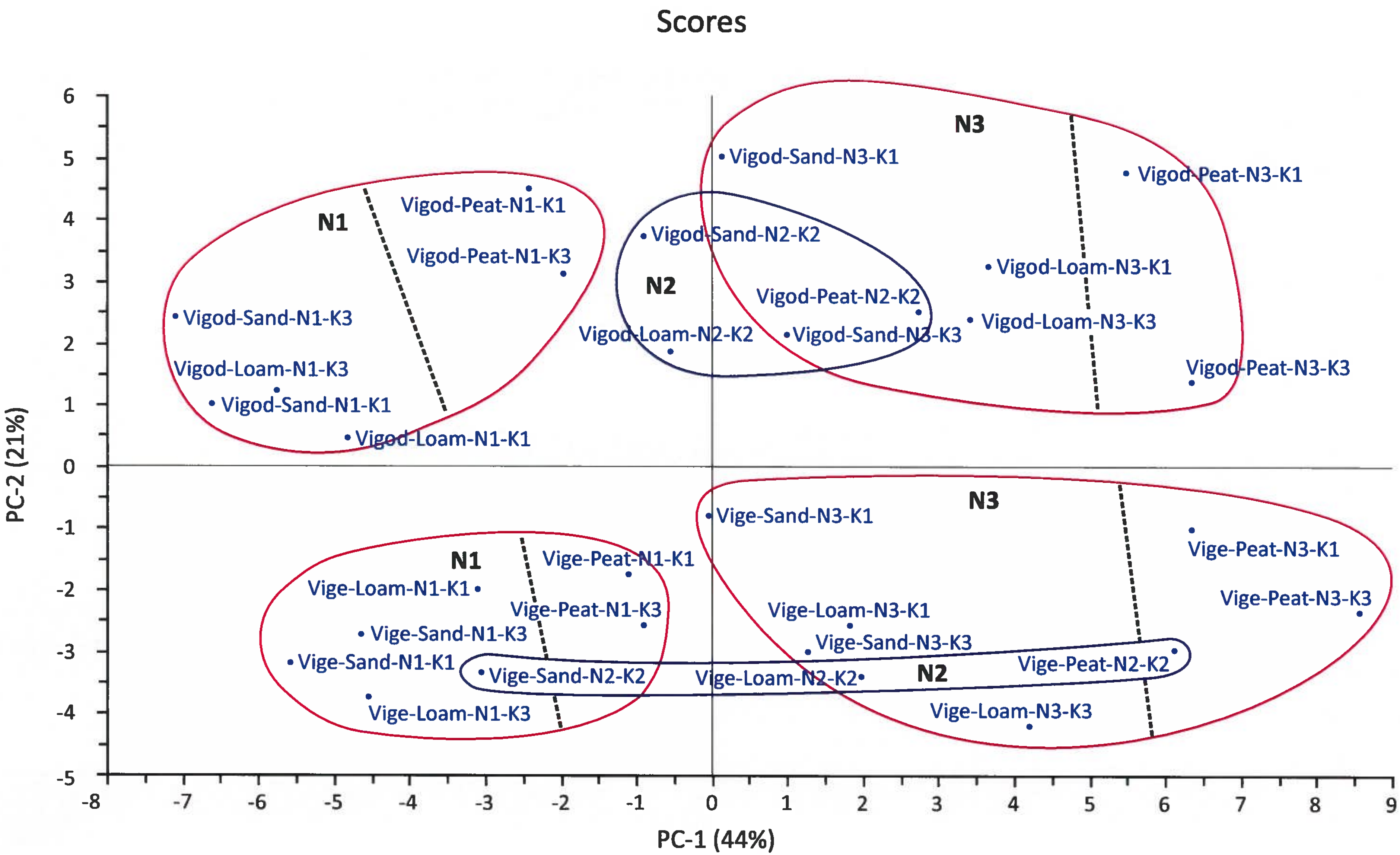
	Variety		Soil type			N (kg ha^{-1})		
	'Vige'	*'Vigod'*	Sand	Loam	Peat	0	80	160
Colour								
Colour intensity	4.2a	3.7b	4.1	4.0	3.9	4.3a	4.0b	3.7c
Colour hue	3.8a	3.5b	3.7	3.7	3.6	3.9a	3.7ab	3.4b
Whiteness	5.4b	5.7a	5.6	5.6	5.6	5.4b	5.6ab	5.8a
Odour								
Odour intensity	6.0a	5.9b	5.9	5.9	6.0	6.0	6.0	5.9
Acidic odour	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
Green odour	1.4	1.6	1.5	1.5	1.6	1.5	1.4	1.6
Soil odour	2.5	2.7	2.5b	2.5b	2.8a	2.4b	2.6ab	2.7a
Pungent odour	3.2	3.0	3.0	3.1	3.2	3.1	3.1	3.1
Sulphurous odour	4.9a	4.4b	4.5	4.7	4.7	4.7	4.7	4.6
Taste and flavour								
Flavour intensity	6.2a	6.0b	6.1	6.1	6.2	6.0b	6.1ab	6.3a
Acidic flavour	3.7	3.8	3.8	3.7	3.8	4.2a	3.6b	3.4b
Sweet taste	3.9	4.0	4.2a	3.9b	3.6c	4.3a	3.8b	3.6c
Bitter taste	4.3a	3.9b	3.8b	4.1ab	4.5a	3.6c	4.2b	4.6a
Green flavour	1.9	1.9	1.9	1.9	1.9	1.9	1.8	1.9
Soil flavour	2.4	2.5	2.3b	2.4ab	2.6a	2.2c	2.6b	2.7a
Pungent flavour	4.1a	3.3b	3.4b	3.7ab	4.1a	3.1c	3.8b	4.3a
Sulphurous flavour	4.6a	4.2b	4.3	4.5	4.4	4.0b	4.5ab	4.7a
Stale flavour	1.5	1.6	1.6	1.6	1.6	1.5	1.6	1.7
Astringency	2.2a	1.9b	1.9b	2.0ab	2.2a	1.7b	2.1ab	2.4a
Aftertaste	4.3a	3.8b	3.9	4.0	4.2	3.6c	4.0b	4.4a
Texture								
Firmness	5.1a	4.8b	5.0	5.0	5.0	5.0	5.0	5.0
Crispness	5.3a	4.9b	5.0	5.1	5.2	5.0	5.2	5.1
Juiciness	5.1b	5.4a	5.2ab	5.1b	5.4a	5.3ab	5.4a	5.2b
Fibrousness	2.6	2.7	2.8	2.7	2.5	2.8	2.5	2.6

Table 8. Five different samples of swede with various growing conditions. Preference tested by 115 consumers on a 9-point scale, score 9 = highly preferred.

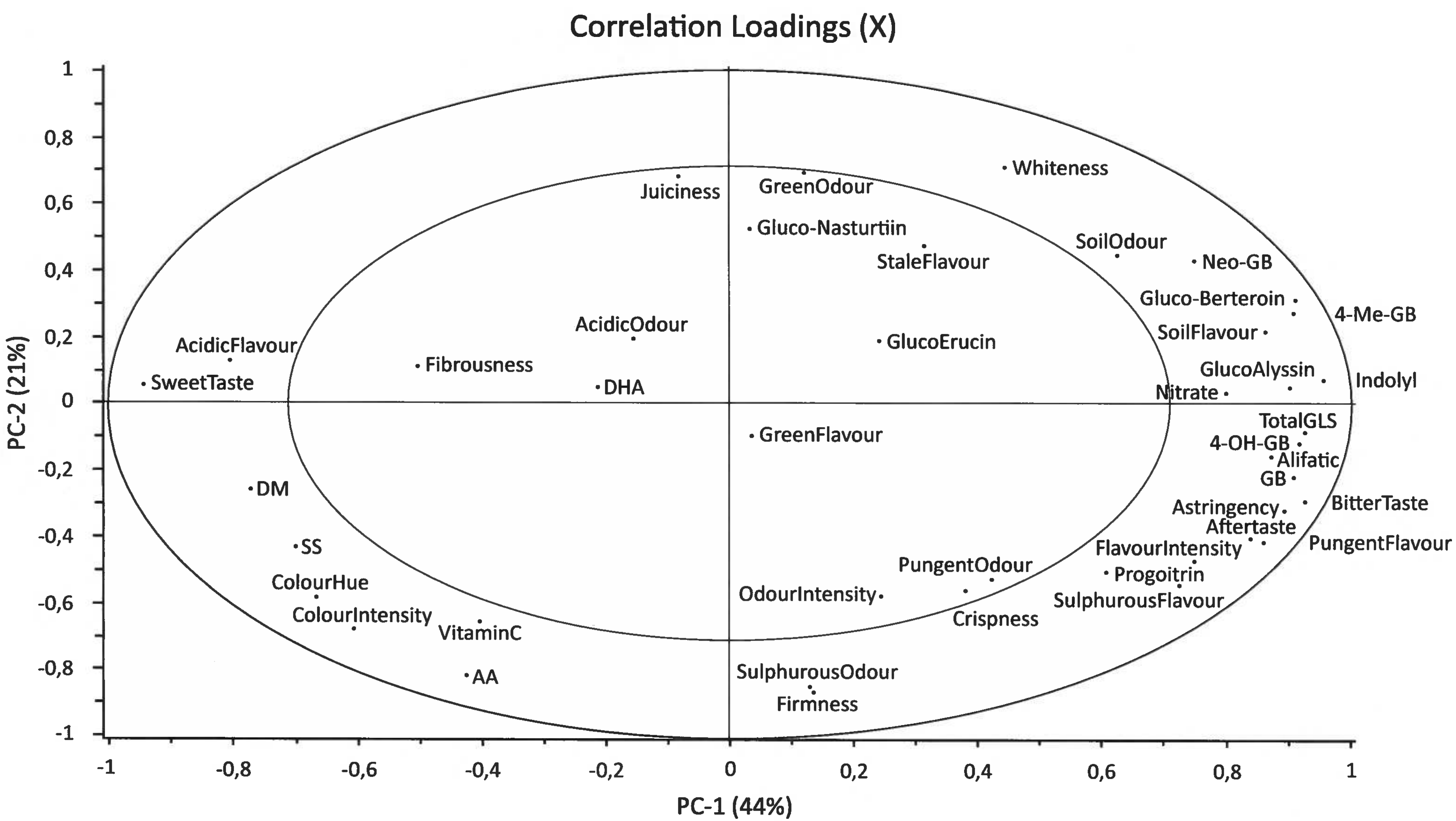
Variety	Soil type	K (kg ha^{-1})	N (kg ha^{-1})	Preference score
'Vigod'	Loam	0	160	5.27^{b}
'Vigod'	Sand	120	80	6.17^{a}
'Vige'	Peat	0	0	5.46^{b}
'Vige'	Peat	120	80	5.15^{b}
Icelandic variety	Peat	120	80	4.03^{c}

Table 6. Effects of cultivar (n=40-43), soil type (n=27-29) and fertilization (N and K, (kg ha^{-1}) (n=15-18) on glucosinolate contents of swedes (mean, mmol kg^{-1} dry matter)

	Progo-itrin	Sini-grin	Epipro-goitrin	Gluco-alyssin	Gluco-erucin	Gluco-berte-roin	Gluco-brassi-cin	4-OH-Gluco-brassi-cin	4-MeOH-Gluco-brassi-cin	Neo-gluco-brassi-cin	Gluco-nastur-tiin	Alipha-tic GLS	Indo-lyl GLS	Total GLS
Cultivar														
‘Vige’	11.62	0.25	0.14	0.65	1.02	2.41	0.78	1.28	0.56	1.05	0.31	16.11	3.68	20.10
‘Vigod’	9.88	0.16	0.12	0.58	1.06	2.62	0.54	1.09	0.60	1.26	0.38	14.42	3.49	18.30
p	***	***	**	ns	ns	**	***	**	**	***	***	**	ns	*
Soil type														
Sand	9.69^{b}	0.17^{b}	0.11^{c}	0.53^{b}	0.95^{b}	1.96^{c}	0.50^{b}	1.01^{b}	0.51^{c}	1.11	0.32^{b}	13.42^{c}	3.13^{b}	16.87^{c}
Loam	11.23^{a}	0.19^{b}	0.13^{b}	0.54^{b}	1.05^{ab}	2.33^{b}	0.60^{b}	1.15^{b}	0.57^{b}	1.16	0.34^{b}	15.46^{b}	3.48^{b}	19.28^{b}
Peat	11.32^{a}	0.26^{a}	0.15^{a}	0.78^{a}	1.14^{a}	3.31^{a}	0.88^{a}	1.41^{a}	0.66^{a}	1.21	0.40^{a}	16.96^{a}	4.16^{a}	21.52^{a}
p	***	***	***	***	**	***	***	***	***	ns	***	***	***	***
Fertilization														
N0K0	9.85^{c}	0.10^{b}	0.08^{c}	0.43^{b}	1.00	1.76^{c}	0.33^{c}	0.87^{b}	0.48^{c}	0.83^{c}	0.37	13.23^{b}	2.52^{c}	16.12^{b}
N0K240	10.24^{bc}	0.10^{b}	0.09^{c}	0.45^{b}	1.09	1.64^{c}	0.38^{c}	0.97^{b}	0.47^{c}	0.84^{c}	0.37	13.60^{b}	2.65^{c}	16.63^{b}
N80K120	11.35^{ab}	0.25^{a}	0.14^{b}	0.67^{a}	1.12	2.78^{b}	0.78^{b}	1.29^{a}	0.59^{b}	1.26^{b}	0.36	16.32^{a}	3.92^{b}	20.60^{a}
N120K0	10.55^{abc}	0.27^{a}	0.17^{ab}	0.75^{a}	0.95	3.39^{a}	0.73^{b}	1.33^{a}	0.66^{ab}	1.39^{ab}	0.33	16.07^{a}	4.12^{ab}	20.51^{a}
N160K240	11.52^{a}	0.31^{a}	0.18^{a}	0.77^{a}	1.04	3.04^{ab}	1.03^{a}	1.44^{a}	0.70^{a}	1.48^{a}	0.32	16.87^{a}	4.65^{a}	21.84^{a}
p	***	***	***	***	ns	***	***	***	***	***	ns	***	***	***



Scores
PC-1 (44%)
PC-2 (21%)
N1
N2
N3
Vigod-Peat-N1-K1
Vigod-Peat-N1-K3
Vigod-Sand-N1-K3
Vigod-Loam-N1-K3
Vigod-Sand-N1-K1
Vigod-Loam-N1-K1
Vigod-Sand-N2-K2
Vigod-Loam-N2-K2
Vigod-Peat-N2-K2
Vigod-Sand-N3-K3
Vigod-Sand-N3-K1
Vigod-Peat-N3-K1
Vigod-Loam-N3-K1
Vigod-Loam-N3-K3
Vigod-Peat-N3-K3
Vige-Sand-N3-K1
Vige-Peat-N1-K1
Vige-Loam-N1-K1
Vige-Peat-N1-K3
Vige-Sand-N1-K3
Vige-Sand-N1-K1
Vige-Sand-N2-K2
Vige-Loam-N1-K3
Vige-Loam-N2-K2
Vige-Loam-N3-K1
Vige-Sand-N3-K3
Vige-Peat-N2-K2
Vige-Loam-N3-K3
Vige-Peat-N3-K1
Vige-Peat-N3-K3



Correlation Loadings (X)
PC-1 (44%)
PC-2 (21%)
Whiteness
Juiciness
GreenOdour
Gluco-Nasturtiin
StaleFlavour
SoilOdour
Neo-GB
Gluco-Berteroin
4-Me-GB
SoilFlavour
GlucoAlyssin
Indolyl
Nitrate
AcidicOdour
GlucoErucin
AcidicFlavour
Fibrousness
SweetTaste
DHA
GreenFlavour
TotalGLS
4-OH-GB
Alifatic
GB
DM
Astringency
BitterTaste
Aftertaste
PungentFlavour
SS
FlavourIntensity
Progoitrin
PungentOdour
ColourHue
OdourIntensity
SulphurousFlavour
ColourIntensity
VitaminC
Crispness
AA
SulphurousOdour
Firmness