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Soybean (Glycine max) cropping in Sweden – influence of row distance, seeding date and suitable cultivars

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ABSTRACT
Field trials were conducted 2010–2012 in soybeans (Glycine max (L.) Merr.) to investigate cultivar choice, suitable seeding dates and row distances for cropping in Sweden. The cultivar trials showed that commercially available varieties of the 000-group can be used for cropping in Sweden. Yield typically amounted to 1500–2500 kg ha^{-1} of dry marketable seeds. Cultivars introduced to Sweden should be tested in the field before large-scale production as the 000-classification not fully is valid for Swedish conditions. Row distance (12.5; 25 and 50 cm) had no overall statistically significant impact on yield, but 25 or 50 cm are recommended as these distances are suitable for physical weed control such as row cultivation or torsion weeding. Seeding in the period May 15–30th is recommended to secure germination and yield. The outcome of the trials was supported by results from field demonstrations and commercial cultivar trials in 2013–2014.

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Introduction

The soybean (*Glycine max*) is native in Asia (Singh 2010; Miladinovic et al. 2011) and has during the twentieth century become one of the most important crops in the world for animal feed and various foods. The European production of soybean is concentrated to the south and southeast regions with countries such as Ukraine, Italy, Serbia and Romania (Table 1) as major producers (FAOSTAT 2020). The production in the European part of Russia is focussed to areas west of river Volga.

The soybean is an annual short-day plant producing seeds with high content of protein (40–45%) and oil (15–20%) (Miladinovic et al. 2011). However, cultivars insensitive to photo-period have been available since mid-1940s by, e g Holmberg & Söner AB, Norrköping, Sweden. The sensitivity to photoperiods and requirement for adequate temperature for flowering and seed production has caused the division of soybeans cultivars into 13 maturity groups from X to 000. In international soybean communities, the maturity group 000 contains those soybean varieties requiring less than 2400 Crop Heat Units (CHU). They are considered as the most early maturing cultivars and can be cropped in regions with long days such as in Scandinavia. Cultivars belonging to the 000 (triple zero) and 00 (double zero) groups are cropped in countries such as Canada, Czech Republic, Austria, Poland and Germany and have been introduced to Sweden (Fogelberg 2004).

The idea of a Swedish soybean cropping has been a challenging thought since the late 1930s. The pioneer in Swedish soya breeding was Mr Sven Holmberg at the breeding company Algot Holmberg & Söner AB located in Fiskeby, Norrköping who already in 1938 began to collect local soybean varieties in Japan and northern China (Holmberg 1946; 1956) for breeding of varieties suitable for Swedish conditions.

The breeding of soybeans by Holmberg and co-breeder Knut Träff (Träff 1979) during the 1940s to 1970s resulted in the well-known series of 'Fiskeby I-V' which all were adapted for cropping at latitude 58° N. 'Fiskeby V' was released on the market in 1968 and was later on followed by cv. 'Träff' and 'Bråvalla' before the breeding program was terminated in the 1980s in connection with a company merge.

Yields of these early Swedish varieties could be surprisingly high. Unpublished data in 1950 (Holmberg 1950) show that seed yield of some breeding lines in some cases had been as high as 2 265 kg ha^{-1} (Table 2). The line 201-14 was later introduced on the market as Fiskeby III.

Unfortunately, the Swedish soybean cropping never became a success. Although suitable for the climate (Holmberg 1973; Elovson 1984), the short plant height of 25–40 cm made harvest difficult (Bengtsson and Larsson 1979). The low yields and general lack of interest from feed industry resulted in a close down of breeding activities in the 1980s.

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Table 1. Acreage, yields and total production of soya beans of the main production countries in Europe 2018 (FAOSTAT 2020).

Country	Area harvested (ha)	Average yield (MT ha^{-1})	Production (MT)
Russia	2,740,850	1.47	4,026,850
Ukraine	1,728,700	2.58	4,460,770
Italy	326,587	3.48	1,138,993
Serbia	196,472	3.28	645,607
Romania	168,709	2.75	465,609
France	153,747	2.60	400,292
Croatia	77,087	3.18	245,188
Austria	67,624	2.72	184,342
Hungary	63,013	2.82	178,200
Slovakia	45,304	2.30	104,525
Czech republic	15,230	1.65	25,259

The long period of breeding activities did unfortunately not result in any major impact in Swedish agriculture why it is a common opinion that soybeans cannot be cropped in Scandinavia. In early 2000 and onwards, initiatives on soybean cropping in Sweden (Fogelberg and Wahlund 2011; Fogelberg et al. 2012; Fogelberg and Lagerberg Fogelberg 2013) partly has changed this opinion due to an increased search for domestic high-protein sources.

In contrast to Scandinavia, breeding activities in, e.g. Canada, Switzerland, Austria and Poland has continued and resulted in modern varieties suitable for cropping in Central and North-Central Europe. These cultivars are today available through a wide range of seed companies in Austria (e.g. Saatbau Linz, www.saatbau.com), Czech republic (e.g. Prograin ZIA, www.prograin-zia.com), France (e.g. RAGT, www.ragt-semences.fr) and Estonia (Estonian Crop Research Institute, ECRI, www.etki.ee).

From a Swedish perspective, a domestic production of soybeans would be valuable in many perspectives; a new legume crop is beneficial from a crop rotation point of view. Swedish agricultural production is today dominated by grains and thus there is a need for legumes such as soybeans, faba beans and peas. Moreover, the use of soya-based feed for pig meat, milk and poultry has been recognised as problematic from a consumer perspective as it is connected to climate change and deforestation in South America. However, turning from imported soybeans to domestically grown beans for production of feed requires basic knowledge of cropping methods such as cultivar choice, fertilisation, seed rate and row distances, harvest technology and production economy.

Table 2. Yield of soya beans lines in trials conducted at Fiskeby (close to Norrköping, Sweden) by Algot Homberg & Söner.

Yield in kg ha^{-1}				
Line or variety	Year			
	1946	1947	1948	1949
201-14	1882	1810	1686	1729
201-14-5 (average of 28 plots)	2265	1718	1980	1817
201-14-15 (average of 28 plots)	1787	1954	1665	1831
201-14-18 (average of 28 plots)	2095	1680	1572	1881
Aojiro (reference variety)	1149	1040	–	–
Manitoba brown (reference variety)	–	–	596	1163

Note: Original table modified by Fogelberg.

In this study, we have revisited the possibility to crop soybeans in Sweden. The aim was to (i)study effects on yield by three row distances (12.5; 25 and 50 cm, respectively); (ii) study effects on yield by seeding dates (early, mid and end of May) and (iii) in cultivar trials study and for further production suggest, suitable cultivars. Some applied aspects on cropping were also included as on-farm cropping and demonstrations for advisory service officers.

Material and methods

Field experiments were carried out in Sweden in 2010–2013. The experiments were conducted at two main geographical areas; in the region of Skåne (southern Sweden, 55°4′N, 14°18′E) and on the island of Öland (56°33′N, 16° 25′E) in the Baltic Sea. The field trials were seeded and maintained by the regional Rural Economy and Agricultural Societies, an organisation specialised in private and public field trials and agricultural advisory services for farmers. Additional field trials and on-farm demonstrations were conducted on the island of Gotland and on the mainland in east Sweden. The seed company Scandinavian Seed AB (SSD) conducted in cooperation with the author, in 2012–2014 a series of field trials on suitable cultivars in Sweden. Parts of these results have been included.

In all experiments, including those carried out in cooperation with the Scandinavian Seed AB, a randomized complete block structure was used with four replications. Each plot was 2-m wide × 12-m long using 50 cm as standard row distance, except in the trial testing different row distances, where 12.5; 25 and 50 cm were used. In general, we used a seed rate of 140 kg ha^{-1} regardless of row distance and a seeding depth of 4–5 cm. This seed rate resulted in a plant density of about 65 plants m^{-2} or 30–35 plants per row meter using 50 cm row spacing; 15–20 plants using 25 cm and 8–10 plants using 12.5 cm spacing. Plant emerged after 7–10 days, flowering took place in early to mid of July followed by pod setting. Full maturity was generally obtained in late September-early October. When plants had matured a net plot of 2 × 9 m was machine harvested using a Wintersteiger plot combine. By harvesting a shorter plot than seeded, we minimised risk of mixing harvested seeds between plots. The harvest was weighed, dried and cleansed. Yield is generally presented as marketable yield in kg ha^{-1}. Some samples were analysed on content of protein (N * 6.25, Dumas; LidNärOA.34), ash (152/2009 EU mod) and amino acids (SS EN-ISO 13903:2005). These analyses were carried out by Eurofins Food & Agro Sweden AB.

Commercially available cultivars were used in the experiments. Two varieties were selected for use all three years, 'Bohemians' and 'Silesia', both originating from the Czech seed company Zemedelska agentura sro, ZIA (today Prograin ZIA, www.prograin-zia.com). The cultivars 'Bohemians' and 'Silesia' were chosen as the general varieties due to their earlier proven ability to mature in temperate climate zones. The 'Bohemians' is bushy type with plant height of about 90 cm, while the 'Silesia' is semi-bushy type that can reach a plant height of 130 cm. 'Bohemians' is considered as a true 000-variety, while the 'Silesia' is a 00-variety approaching the 000-group, that requires a higher temperature sum (2390 UTM) compared to 'Bohemians' (2375 UTM). Cultivars used in the SSD-trials were either obtained from commercial producers or as samples from research institutes, universities and small-scale producers in the northern hemisphere.

In general seeds were untreated, but in the SSD cultivar trials, 'Merlin', 'Gallec' and 'Obelix' had been pre-inoculated with an unknown *Bradyrhizobium japonicum* product regardless of experimental year. To standardise inoculation, all seeds were prior to seeding inoculated with a commercial product (Hi-Stick) containing *Bradyrhizobium japonicum* obtained from Becker Underwood, today sold under the name Nodulator® by BASF. The varieties were all GM-free.

Due to lack of funding, only one cv. 'Bohemians' was used in the row distance trial, whereas 'Bohemians' and 'Silesia' were used in the seeding date trials.

Seedbed preparation was done by two harrowings followed by fertilisation with 150 kg ha^{-1} Yara PK 7-25. Seeding took place with a Wintersteiger plot seeder. Weeds were controlled with herbicides (one spraying with Sencor + Centium 0.4 + 0.4 l ha^{-1} pre-emergence) and repeated inter-row hoe cultivations until canopy-covered row spacing. No treatments on fungi diseases were carried out.

The harvest was conducted in late September or early October. Plots were machine harvested, generally during one working day, but in some cases, harvest continued after a 12 h break. The seeds from each plot were dried at the Torslunda Agricultural Research Station and stored until cleansing could be done by the author.

Statistical analyses

Results were analysed by the author using Tukey's HSD in a multifactor ANOVA. Software (Statgraphics Centurion XIV) was provided by Statgraphics Technologies Inc., USA.

Results and discussion

A problem noticed in the field demonstrations were damages by birds after emergence of plants up the first true leaf stage. Pigeons and crows were very attracted to the dark green colour of the seedlings even if we had taken measures to minimise bird attacks. We used nets to prevent rabbits and roe deer to enter the trials. Gas cannons, kites and vibrating plastic bands were used in the trials to prevent damages by birds. There were no visual losses of plants or yield due to animals except in 2012 when one trial had to be discarded (Table 3).

Cultivar choice, yields and maturity

The yields varied significantly between years and cultivars; in the SSD cultivar trial 2012–2014 in Skåne (Table 4) 'Bohemians' yielded between 1510 and 2900 kg ha^{-1}, while on Öland in 2010–2012 the yield amounted to 1140–1980 kg ha^{-1}. In 2014, yields were in some cases doubled compared to those achieved in 2012, an unusual wet and cold year. In 2013, Sweden experienced a quite normal year from a meteorological point of view. In the SSD trials yields of the nine tested cultivars varied between 1298 (Merlin) to 1820 (Gallec) kg ha^{-1}. The majority of the cultivars typically yielded about 1600 kg ha^{-1}. A similar trend was found in 2012 with yields of about 1400 kg ha-1 and in 2014 of 2700–3000 kg ha^{-1}.

In these trials yields typically amounted to 1500–2500 kg ha^{-1} regardless of variety. Warm season may increase yields for some cultivars to about 3000 kg ha^{-1} and wet, cold years lower yields to about 1400 kg ha^{-1}. In comparison, the average soybean yield of Europe in 2018

Table 3. Yield of soya beans in kg ha^{-1} corrected to 8% moisture.

Cultivar	Test site					
	Öland			Skåne		
	2010	2011	2012	2010	2011	2012
Bohemians	1140a	1980b	x	1500c	1860c	1450c
Silesia	800a	2640c	x	1120ab	1100b	1270b
Tundra	1110a	1730b	x	–	–	–
SL96068.06	1140a	1080a	x	1240bc	1150b	850a
Brunensis	–	–	–	–	–	1040bc
Kenchawol	–	–	800a	–	–	–
Favorit	–	–	–	–	470a	–

Notes: x, trial is excluded due to damages by birds or roe deer. –, not included for testing. Yields with the same letters are not statistically separated at the 95% level using Tukey's HSD test.

Table 4. Yield of soya beans in kg ha^{-1} corrected to 15% moisture.

Cultivar	Test site		
	Skåne		
	2012	2013	2014
Bohemians	1510abc	1701bc	2900bcd
Silesia	1405ab	1632abc	3306cd
Fiskeby V	–	1506abc	2003a
Obelix	13811ab	1644bc	3251cd
Brunensis	1556abcd	1627abc	3584d
Moravians	1383ab	1672bc	2106ab
Merlin	1945d	1298a	3322cd
Gallec	1925cd	1820cd	2701abc
Paradis	1771bcd	1556abc	2706abc

Notes: Data from Scandinavian Seed AB trials carried out by the author. –, not included for testing. Yields with the same letters are not statistically separated at the 95% level using Tukey's HSD test.

was 2130 kg ha-1 and in 1565 kg ha^{-1} in 2012 (FAOSTAT 2020).

The lower yields of Sweden compared to e g Germany (average yield of 2458 kg ha^{-1} in 2018; FAOSTAT 2020) is likely connected to the overall lower summer temperature and partly the long days. Soybean have a higher need of warmth than e g wheat or faba beans to germinate, develop and flower (Gibson and Mullen 1996; Miladinovic et al. 2011). A temperature above 19°C is required for flowering (Miladinovic et al. 2011) and night temperature less than 8–9°C will cause a pause in flowering (pers. comm. Krause 2013; Gagnon 2016). In order to provide optimal cropping conditions in a temperate climate zone such as Sweden, care must be taken to choose sandy fields that dry up early in spring, situated in the landscape to avoid frost in spring.

The differences in yield and maturity between the studied varieties imply a variation within the 000-group that obviously is pronounced when the varieties are tested under cool climate conditions. In 2013, we measured days to maturity of a handful cultivars (Table 5) using the SSD-trial in Östergötland (latitude N 58.48; E 15,52); island of Gotland (latitude N 57.37; E18.58) and Skåne (latitude N 55.45°; E 14.16) The differences in maturity between cultivars might be an effect of the breeding material. It is well known that the Fiskeby V is an extremely early maturing variety. It has been confirmed that 'Bohemians' partly is based on breeding material of Fiskeby V (Krause, 2013, pers com.).

The chosen varieties of the maturity trial were all in the 000-group although full maturity could vary between 113 and 138 days in Skåne (southern Sweden), respectively, 129–164 days in south central Sweden (Östergötland). 'Moravians', 'Paradis' and 'Bohemians' were from a maturity perspective, less affected by the geographical site compared to 'Gallec' and 'Merlin'. From an agricultural point of view, varieties that show small differences in days-to-maturity should be used. Depending on annual differences in weather, we can speculate that cultivars with a pronounced difference in days-to-maturity such as 'Merlin' or 'Gallec', can mature late even in the south part of Sweden and possibly not reach maturity in northern areas in a wet and cold season. Hence, on introducing new varieties regional trials should be carried out to establish recommendations for farmers. In a Swedish perspective, the 000-group can contain cultivars being associated with the 00-group and thus not suitable for Scandinavian conditions.

Table 5. Days to maturity in 2013 at three test sites.

Cultivar		Test site		
	Maturity difference (days)	Östergötland	Gotland	Skåne
Obelix	19	146	132	127
Gallec	22	146	134	124
Bohemians	13	131	124	118
Silesia	18	156	142	138
Merlin	36	164	146	128
Moravians	10	148	140	138
Brunensis	17	141	140	124
Paradis	12	129	122	117
Fiskeby V	–	–	–	113

Note: Data from trials of Scandinavian Seed AB, Sweden carried out by the author.

Row distances and seeding dates

There was no clear tendency on how row distance influenced yield (Table 6). Using a 12.5 cm row distance resulted in yields of 1488–2000 kg ha^{-1}, while 25 and 50 cm row spacing yielded 1492–1934 kg ha^{-1}, respectively, 1538–1944 kg ha^{-1}. In the Öland trial, there were no statistical differences between row distances neither in 2010 ($p = .56$) nor in 2011 ($p = .90$). The 2012 experiment was discarded due to damage by animals (roe deer). The Skåne trials showed that 12.5 cm distance yielded significantly better than 25 and 50 cm, respectively, in 2010 ($p = .0002$) and 2011 ($p = .0006$), while there were no differences in 2012 ($p = .36$).

Saaten Union Company (www.saaten-union.com) recommends for Germany row distances of 13.5–35 cm and wider distances of 40–50 cm in case mechanical weed

Table 6. Yield of soya bean 'Bohemians' at two sites using three row distances.

Year	Yield kg (ha-1)					
	Öland			Skåne		
	12.5 cm	25 cm	50 cm	12.5 cm	25 cm	50 cm
2010	1964c	1934c	1624bc	2000c	1630b	1944c
2011	1488a	1492a	1538a	1985b	1760a	1690a
2012	x	x	x	1800a	1742a	1820a

Notes: Moisture content of yields varies between 8 and 14%. X = trial damaged by animals, discarded. Yields with same letters are not statistically different at the 95%-level using Tukey HSD.

control is applied. Danube Soya, a non-profit organisation for European soya producers, traders and processor recommends a row spacing of 50 cm (Rittler et al. 2020). In USA and Canada, row spacing of 30 in. (76 cm) is common although narrow spacing of 15 in. (38 cm) has proven to increase yield (Pedersen 2020).

The statistical differences obtained in yields are probably more connected to the seasonal variations in rainfall and temperature, than row distance itself. There is, however, an agronomical point of view that should be considered. In Swedish grain production 12.5 cm row distance is commonly used (Hammar 1978; Boström et al. 2012) why seeding machines in general are preset to this distance. Equipment used for seeding of sugar beets, field beans and various vegetables often uses a row distance of 48–50 cm. This row distance allows for physical weed control by hoes, torsion weeders, rotating brushes et cetera, a possibility especially important in organic production and when few herbicides are available. In cool cropping regions such as the Scandinavian countries, it might also be favourable to choose row distances of 25 or 50 cm to allow more sunlight on the individual soya plants and the maturing pods.

The three seeding periods; early (May 4th–May 11th), normal (May 15th–May 31st) and late (June 7th–June 11th) represent periods when seeding of soybean took place. The early period was considered as interesting for a typical grain producer, while the normal period is in line with recommendations based on soil temperature requirements of soybean (approx. 10°C). The late period would be suitable for farmers looking for the following crop after harvest of early potatoes in southern Sweden.

Yields of seeding in the early period varied between 1385 and 2017 kg ha^{-1}; for the normal period between 905 and 2405 kg ha^{-1}, and for the late period between 680 and 1693 kg ha^{-1} (Tables 7 and 8). Although variations in field were recorded, there were few statistical differences in yield (Tables 7 and 8). Seeding in the late period was less favourable for yield, especially in the cold and wet year of 2012.

From a farmers' point of view, 'Bohemians' (Table 7) seemed to be a reliable variety as it yielded between 1500 and 2000 kg ha^{-1} regardless of seeding date and season. The variety is one of the earliest cv. on the market of Prograin origin. It is not clear if the plant type itself – the shorter, bushy appearance – is a feature beneficial for Swedish conditions.

For 'Silesia' (Table 8) seeding in mid of May generally yielded more than early or late seeding ($p = .004$). The somewhat higher heat sum needed for this cultivar to mature may be an explanation; early seeding is often connected with low soil temperature and late seeding will shorten the period of growth and thus lower the total heat sum. As we noticed in the SSD trials in Skåne 2013, 'Silesia' required 138 days to full maturity compared to 118 days of 'Bohemians'. A late seeding of 'Silesia' will negatively affect the ability to reach full maturity, especially cold seasons. For the farmer, choosing 'cultivars such as 'Silesia' is risky; on one hand a warm spring can give an opportunity to seed early and use the full yield potential, while on the other hand, a cool season might result in low (700–1200 kg ha^{-1}) yields.

The findings stress the importance of using true 000-varities with early maturation and low heat sum requirements. An applied aspect is that future field trials should include seeding date as a parameter in evaluating new cultivars for Scandinavia. It might be better to choose varieties that produce an average yield (1500–1800 kg ha^{-1}) regardless of summer temperatures instead of varieties that excel warm summers but give poor results in cold years.

Aspects on cropping practice and future development

The fact that soybean requires high soil temperatures at seeding and during development and few herbicides are allowed for use in Sweden, hamper an expansion of Swedish conventional production. As soybean pods are set close to the soil surface, flexi-headers able to cut plant stems about 30 mm above soil surface is beneficial for reduction of field losses at harvest. Flexiheaders are available for all major combine brands. The current lack of available herbicides may trigger production of organic soybeans sought after by consumers and local/regional feed producers. Tools for physical weed control such as video or GPS-guided hoes or torsion weeders are available on the market reducing the need for herbicide use.

An interesting approach would be harvest of the fresh soybean pods – edamame – a product today imported either fresh or frozen from overseas. Edamame production would likely be more profitable than of mature seeds and could be an interesting alternative for small-scale vegetable farms already used to hand-harvest and handling of produce in a cool-chain from farm to consumers. This system, however, may require the use of plastic tunnels to secure pod development and reduce damages by birds, deer and rabbits.

Conclusions and recommendations

We conclude that soybeans can be cropped in Sweden at latitudes up to about 59° (Stockholm region). Varieties of the 000-group should be used in order to secure yield,

Table 7. Marketable yield in kg ha^{-1} of soya bean 'Bohemians' at two sites.

Seeding date		Year and site					
		2010		2011		2012	
		Skåne	Öland	Skåne	Öland	Skåne	Öland
4 May	early	–	–	2 017c	–	–	–
6 May	early	1 479a	–	–	–	–	–
7 May	early	–	–	–	–	1 847f	–
9 May	early	–	–	–	1 644a	–	–
11 May	early	–	–	–	–	–	1934a
15 May	normal	–	1 892cd	–	–	1 641ef	–
18 May	normal	1 793a	–	1 377ab	2 080b	–	1061b
24 May	normal	–	–	–		–	1194a
25 maj	normal	–	–	–	2 405b	–	–
28 maj	normal	–	1 538b	–	–	–	–
30 maj	normal	–	–	1 846bc	–	–	–
31 maj	normal	–	–	–	–	1 218bcd	–
7 juni	late	–	–	–	1 682a	–	–
10 juni	late	–	1 693bc	–	–	–	–
11 juni	late	–	–	–	–	970ab	–

Notes: Yields corrected to a moisture content of 8%. Yields with same letters are not statistically different at the 95%-level using Tukey HSD.

Table 8. Marketable yield in kg ha^{-1} of soya bean 'Silesia' at two sites.

Seeding date		Year and site					
		2010		2011		2012	
		Skåne	Öland	Skåne	Öland	Skåne	Öland
4 maj	Early	–	–	1 394ab	–	–	–
6 maj	Early	1 820a	–	–	–	–	–
7 maj	Early	–	–	–	–	1 538def	–
9 maj	Early	–	–	–	1 385a	–	–
11 maj	Early	–	–	–	–	–	1240a
15 maj	Normal	–	2 022d	–	–	1 392cde	–
18 maj	Normal	2 023a	–	1 220a	2 100b	–	1736ab
24 maj	Normal	–	–	–		–	1322a
25 maj	Normal	–	–	–	2 308b	–	–
28 maj	Normal	–	1 205a	–	–	–	–
30 maj	Normal	–	–	905a*	–	–	–
31 maj	Normal	–	–	–	–	1 050bc	–
7 juni	Late	–	–	–	1 412a	–	–
10 juni	Late	–	1 452ab	–	–	–	–
11 juni	Late	–	–	–	–	680a	–

Notes: Yields corrected to a moisture content of 8%. * represents overall low yield due to poor (approx. 50%) germination of seeds. Yields with same letters are not statistically different at the 95%-level using Tukey HSD.

but there is a need for regional field trials to specify suitable varieties. Commercial varieties are available from a wide range of seed companies.

Row distance will only to some extent influence yields but a width of 25 or 50 cm is recommended as it allows for mechanical weed control using machines available on the market and often already in use on farms.

Soybeans require a soil temperature of about 10°C to germinate. An early seeding (end of April to early May) may be successful, especially in warm springs and cropping on sandy soils in southern Sweden. However, seeding in the latter half of May will often enhance germination and early development of the plant, thus securing the production. An early seeding may trigger problems with birds eating the soybean shoots after emergence.

We did not carry out any study on the effect of *Bradyrhizobium japonicum* as inoculation for nitrogen fixation. However, an inoculation will lower the need for nitrogen fertilisation and thus lower the production costs. Studies by Andersson (2014) on Swedish farms have shown that *B. japonicum* still is present 3–4 years after a soybean crop, thus minimising the need for additional inoculation.

Further studies on cropping systems including weed control and fertilisation strategies are encouraged.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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