Plantbreeding at Svalöf: Instruments, Registers, Fieldwork.

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The experimental breeding station at Svalöv was installed from resources of the Swedish Seed Association, founded by private entrepreneurs, state officials, and agricultural co-operatives in 1886. The motivation for its foundation was that land reform and mechanisation had created surpluses in agriculture that made export economically interesting for the first time in Swedish history. However, the English and German cultivars that had been imported to Sweden for their high returns did not endure its winter very well – in contrast to the traditionally cultivated, but less yielding, so-called 'country sorts' of Sweden. The expressed concern of the Swedish Seed Association was therefore to test the viability of foreign seed material under the climatic conditions of Sweden, to raise its viability, if necessary, by breeding, and to distribute the material thus tested and ameliorated to the market.

In accordance with this practical orientation a German agricultural engineer, Thomas Bruun von Neergaard, was employed already in 1886. Neergard did not publish on his work, but an impression of his procedures can be gained from his annual reports to the Association and from descriptions of Nils Hjalmar Nilsson (1856 - 1925), who succeeded him as the experimental station's director in 1890. The breeding method Neergard used is known as 'mass selection' and consisted in collecting the best plants, ears, or seeds from each harvest and to sow them out collectively for next year's harvest (Olsson 1993, Roll-Hansen 1990, 104-106). The procedure focuses directly on the quality that is aspired (e.g. large grains) and its effectiveness seems to be intuitively evident. The 'invisible hand' that operates here is that of the breeder himself, as it had been active since ages, and the knowledge it is based upon seems largely to be implicit. A closer look at Neergard's method reveals why it still could claim to be 'scientific' or 'systematic', a claim that was raised from its very onset.

A table published by Nilsson presents the hierarchy of criteria according to which Neergard carried out selection (Nilsson 1892, 126).

	Urval af		
		plantor	
1.			efter *stråbyggnad,*
2.			» *ax* (botaniska, fysikaliska karakterer etc.)
	» »	***ax***	
3.			efter *ursprung,*
4.			» *vigt,*
5.			» *storlek,*
6.			» *täthet,*
	» »	***kärnor***	
7.			efter *plats,*
8.			» *storlek,*
9.			» *vigt.*

Two observations can be made about these criteria:

1. Selection was not carried out according to the overall impression of the plants – their 'vigour' or 'beauty' – but according to certain characters, each of these attended to separately, but all of them successively focussing on the aspired quality, the quality of the grains (kärnor): first, characters of the whole plant, as the 'structure of the straw', had to be assessed, next characters of the ear, as weight, size, and density, and finally characters of the grains, as their position and weight. Moreover, the criteria consisted of well quantifiable or classifiable characters, as weight, sizes, angles or positions. The overall gestalt of the plant was atomised into smallest units of measurable difference.

2. As Neergaard himself noted in one of his reports, the plant material went 'through many hands' (quoted in Olsson 1993, 181). The great mass of material – in the winter of 1899/90 alone, 11000 individual plants of a single sort of barley were examined – and the repetitive pattern of the selection process made it necessary to employ untrained assistants, mostly women and children. According to Neergard, his main aim lay in the factory-like organisation of this work and the mechanisation of each working step by specially developed tools with such names as 'combined barley- and oats-forceps (Kombinierte Gersten- und Haferzange)', 'classificator (Klassifikator)', 'Diaphanoskop', and 'earlet-sorter (Ährchensortierer)'.

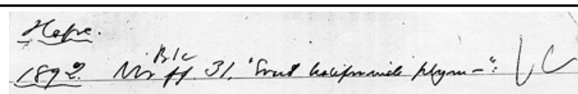
This breeding method of Neergard – called 'systematic breeding' or simply 'the Svalöv-method' – was continued in its main lines by Nils Hjalmar Nilsson. And yet the latter maintained that Neergard had only carried out 'preparatory work for the development and control of a systematic breeding method'. An 'important innovation' had been introduced (Nilsson 1892, 125, 130). This innovation was highlighted in the scheme provided by Nilsson to explain Neergard's method. The category 'botanical, physical characters (botaniska, fysikaliska karakterer)' was inserted into the list in normal type instead of italics. Other than Neeergard, Nilsson had received an education in academic botany, and he thus exhibited a pronounced interest in morphological details. Thus he praised his predecessor for having introduced the 'classificator', an instrument for determining the 'density' of the ears of cereals in a single working step without complicated mathematical operations, but only to add a long discussion of this coefficient, resulting in the statement that 'ear density' correlates with 'strength of stem' and grain number per 100 mm of spindle length. The coefficient of 'density' , according to Nilsson, could thus provide the plant breeder with a means to attend to 'inner developmental dispositions (innere Bildungsanlagen) which until now lay outside his reach'. With 'inner developmental dispositions' Nilsson was referring to the morphological 'laws (Grundgesetze)' that that characterize the morphological structure of a plant (Anonymous 1890, 29-33).

Nilsson's way of reasoning was common among botanists at the end of the 19th century: It lay at the ground of taxonomically distinguishing plant species or varieties according to their morphological type, which, in its turn, was believed to be determined by (quasi-mechanical) laws of growth (Lenoir 1982). As a consequence, Nilsson saw his chief task in establishing and organising a collection of deviating forms (Nilsson 1892, 133). Already in the first two years of his appointment, Nilsson raised the number of cultivated cereal strains to 2000, each of these strains occupying its own, little parcel on the experimental station's acres (Anonymous 1893, 85). To grow this enormous number of varieties had become possible through an institutional reorganisation that the Swedish Seed Association underwent when Nilsson became its director.

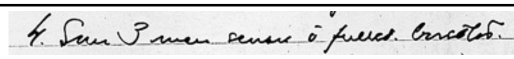
As already mentioned, the association, at its foundation, also had the task to distribute the grains it tested for good to the market. This had the consequence that a large part of the area at the experimental station was used for the mass production of seed. The Association did effectively not do anything different from any other commercial plant breeding company. It was only with the foundation of a separate and independent joint-stock company in March 1891 – which alone should be responsible for the selling of seed raised at the experimental station at Svalöv, and which, as a matter of course, had exclusive access to this material – that the necessary space was opened to realise the type collection Nilsson envisioned. Correspondingly, Neergard's principles – to better those strains that had already proved to be the best, rather than collecting all sorts of strains – could only be 'thrown over board' after that institutional change had come about. As a matter of fact, Neergard left his directorship in protest against this change, which he viewed as going against the interest of commercial plant breeders and farmers, the clients he felt himself obliged to (Neergaard 1890).

There was another change occurring at Svalöv with Nilsson's directorship: While Neergard could be content with proving that he had achieved yield increases in each of the annual reports he delivered to the Association, Nilsson's method was in need of records that allowed to observe the development of individual 'types' comparatively and over successive generations (Welinder 1891: 7). This was provided by a system of records that consisted of three elements: a 'journal of analysis', that recorded the results of comparative tests for yield potential of different strains; 'descent cards (härstamningskort)', i. e. annual lists of which strains had been cultivated on which parcels; and finally, 'field books (fältböcker)', in which a number of observations on each cultivated strain was put down for each year. The latter two together were called 'register (stambok)', in analogy to a family register. The journal of analysis was mainly used to decide which strains were to be passed over to the joint-stock company for marketing, and mainly consisted of tables recording chemical and biological properties as measured in the laboratory. The register had a more complicated structure, that I want to explain in some detail in the following.

The descent cards were started in 1892, and show the following structure. The headline states the grain species (e.g. 'Hafre', i.e. oats), the year ('1892'), the number of the parcel it referred to ('B.I.e. ff. [i.e. försöksfält = experimental parcel] 31"), and the variety that was cultivated on that parcel (e.g. 'Svart, kalifornisk plym-', i.e. black, Californian plume-oat). The number for the parcel results from a complicated classification of fields and parcels according to species sown out and the season of sowing (see Anonymous 1892: 99-100).

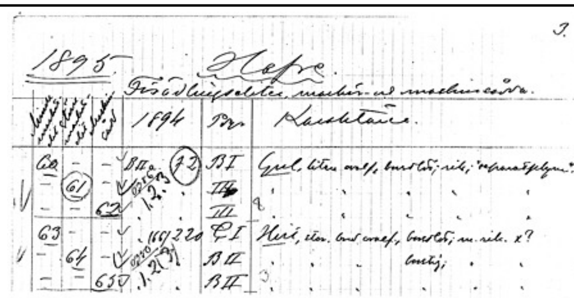

Hafre.
1892. Nr B.I.c ff. 31. 'Svart kalifornisk plym-'

Under this heading, a list of numbered entries follows, distinguishing different strains within the variety grown on the parcel according to botanical criteria, as the colour of the seed, the form of the ear etc. These botanical characterisations were elaborated comparatively, that is by listing differences only, not by independent description, as is clear from formulations like '4. Like 3 but later and without any bristles (4. Som 3 men senare och fullst. borstlös)'.


4. Som 3 men senare o fullst. borstlös.

Following the so-called pedigree method, developed by the French seed company Vilmorin, one individual was isolated from each of the distinguished strains and all its seeds sown out in the following year on a separate parcel. The descendants of this individual constituted what was called a 'pedigree', the assumption being that unity of descent would guarantee the 'purity', and thus, stability of the pedigree (Gayon and Zallen 1998).

If one takes a look at the descent cards from the following years, the way in which the development of pedigrees could be followed from year to year (generation to generation) becomes clear. The original lists from 1892 become tables, whose columns contain, from left to right, the parcel numbers (their number rising continually), a running number (whose function is unclear to me and which later records lack), a designation for the 'origin (Ursprung)' in 1892, the number of seeds sown out on the parcel, and finally observations on seed colour, time of ripening a. s. o. The 'origin' was accounted for by the number of the parcel from which the pedigree had been isolated in 1892 (as 'B.I.e ff. 31') plus the number for the individual pedigree on that parcel. In the following years, then, it was only necessary to correlate the parcel numbers of the current year with the parcel numbers of the previous year (columns 1 to 4) to retrace the plants growing on each parcel in each successive year to their 'origin' from individual plants in 1892 (designated as 'Pdgr.' in column 5). As in each year deviating botanical characters of the plants on each parcel were carefully noted (under 'Karaktärer'), it was possible to observe their behaviour – stable or variable – in the course of generations. Stable pedigrees were retained, variable ones either further 'purified' or abondened. Thus some of the successfully marketed grain sorts from Svalöv can be retraced to a single ear sown out in 1892 (see Anonymous 1936, 54-56).



In the beginning, botanical observations were inserted into the descent cards directly. But they soon found their own place in so-called field books, which were correlated with the descent cards by the parcel numbers. Thus a lot more space was created for these observations. I will discuss these entries in some more detail below. A further innovation consisted in the introduction of 'register numbers (stamboksnummer)'. On the descent card from 1895 shown above – which also shows with its mass of ticks and underscores how intensely the descent cards were reworked in later years – they are inserted obliquely as underlined four-digit numbers. These numbers were assigned to pedigrees if these had proved to be somewhat stable, and when they seemed promising in terms of yields.

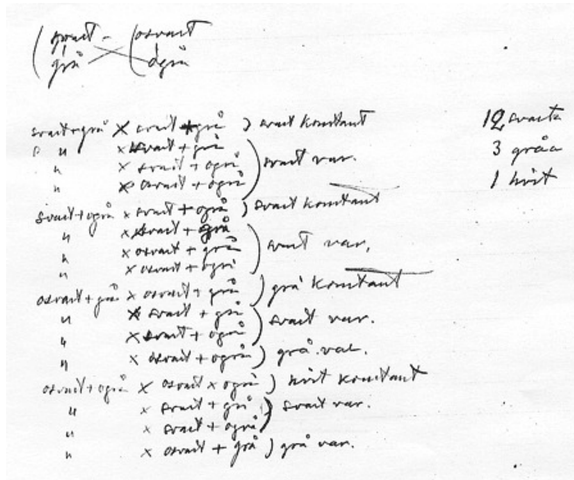
Such register numbers always remained the same in contrast to the parcel numbers, which changed annually as the plants were moved from one parcel to the other to avoid the leaching of the soil and the production of high or low yields by coincidental circumstances. Register numbers thus designated pedigrees as stable, and effectively immutable units circulating within the well-developed system of fields and parcels on Svalöv and its subsidiary experimental stations (Nilsson 1893). They were 'elementary species', 'independent, systematic units', as Nilsson would designate them in an article summarising his views on plant breeding in 1907. In a sense, that is, they were atoms of the taxonomic discourse, and correspondingly, as species and varieties in systematic botany, they received immutable names in form of their register numbers. The breeder could only chose among them, a slow and continuous transition from one to the other, as presupposed by mass selection, had to appear as impossible (Nilsson 1907). Plant breeding, in the words of Nilsson, had become a 'lottery', and chances in that lottery could only be raised by cultivating the highest number of isolated types (Nilsson 1892, 131).

It was in this context of systematic collection and record keeping that Herman Nilsson-Ehle (1873 - 1949), a young plant physiologist from the University of Lund who had become research assistant at Svalöv in 1900, started to perform Mendelian experiments. One of these experiments began in 1903 with an artificial crossing – artificial in as much as oats is a species subject to obligatory self-fertilization – of two pedigrees of oats, which had been cultivated at Svalöv for a long time already and carried the register numbers 0353 and 0462, later changed to 0668. A field book entry for pedigree 0462 from the year 1903 contained, as all field book entries did as a rule, the following information: the year of the entry in the upper left hand corner; the number of the parcel from which the seeds were derived in the previous year in the upper right hand corner; the parcel number and the register number, followed by a detailed botanical description of the plants on the parcel; further information on steps in the development and cultivation of the plant; and finally, the number of the parcel on which seeds from these plants were sown out in the following year 1904. Each field book entry, which as a rule occupied a single page of the field book only, thus represented the plants grown on one parcel as a distinct unit in terms of botanical character, development, cultivation, and descent.

From the artificial crossing of pedigrees 0353 and 0462, four individuals were raised in 1904 on one parcel, for which the field book entries (ff 376 recto, ff 376 verso) look similar, if only differentiated for each individual ('376a-d'). As expressly stated in the entries c and d ('lik 376a'), and as to be expected by the Mendelian rules for the first hybrid generation, the four plants were similar to each other, except for 376b, which was said to possess slightly shorter seeds. The seeds from these four individuals were then sown out on separate fields in the following year. Now, however, the field book entries (ff 233 recto) exhibited a completely different structure: A botanical description of the plants growing on each of the parcels was lacking. Instead a single category – the colour of the seed – was observed in regard to the absolute frequency with which its alternatives appear on the parcels (small column in the right hand middle of the page): '8 grey (gråa)', '4 white (hvita)', '207 black (svarta)', in various shadings ('mörkare', 'ljusare'). Contrary to Mendelian expectations, colour did not segregate discretely, and not at all in a 3:1 proportion.

It is these absolute frequencies, tabulated in a little diagram for the descendants of each of the four plants raised in 1904 ('a, b, c, d'), and their strong deviation from what should be expected from Mendelian rules, to which an essay refers that Nilsson-Ehle published in 1907 and in which he maintained – in open opposition to his superior Nils Hjalmar Nilsson's morphological point of view – 'that it can happen, that what appears to us as one property, may in fact be a composite of several properties' (Nilsson-Ehle 1907, 214-215). Why this should be so, however, is not explicitly discussed in this essay. Only a year later, in a contribution to a professional botanical journal, did Nilsson-Ehle interpret his findings under the assumption, that the 'black colour consists of two independent units (unabhängige Einheiten)' and that its hereditary pattern therefore follows the 'dihybrid scheme' of Gregor Mendel (1822-1884) (Nilsson-Ehle 1908, 266). In maintaining this, the table presented in 1907 was extended in three respects. First, the absolute frequencies were transformed into relative frequencies; second, the sum (the mean) was drawn from the absolute (relative) frequencies; and finally, a symbolic representation was added for the dihybrid scheme. Through this series of mathematical and symbolical operations Nilsson-Ehle brought about an abstraction from the concrete distribution of individuals and pedigrees on fields and parcels that allowed him to present his data as in accordance with the Mendelian rules.

How Nilsson-Ehle reached his conclusions regarding the 'dihybrid scheme' determining seed colour in 1907 is made evident by a leaflet he inserted into the field-book of 1905.



svart – osvart
grå – ogrå

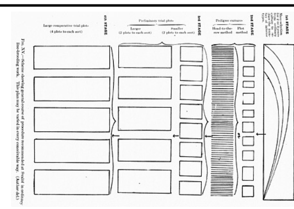
svart+grå × svart+grå) svart konstant
" × svart+grå
" × svart+ogrå
" × osvart+ogrå) svart var.
svart+ogrå × svart+ogrå) svart konstant
" × svart+grå
" × osvart+grå
" × osvart+ogrå) svart var.
osvart+grå × osvart+grå) grå konstant
" × svart+grå
" × svart+ogrå) svart var.
" × osvart+ogrå) grå var.
osvart+ogrå × osvart × ogrå) hvit konstant
" × svart+grå
" × svart+ogrå) svart var.
" × osvart+grå) grå var.

12 svarta
3 gråa
1 hvit

It developed the dihybrid scheme for seed colour by assuming two factors —one for black ('svart'), one for grey ('grå') colour— which in turn might either be present or absent ('un-black [osvart]' and 'un-grey [ogrå]' in the latter case). The possible combinations of these four alternatives in the zygote were listed under a hybridization scheme similar to the one Nilsson-Ehle had used in his annotations to the Mendel paper and should later also use in his printed presentation in 1908. The resultant colour of the seed was derived from these combinations under the assumption that absence of both the factor for black and for grey yields white colour and that black 'covers' grey, i.e. yields the same black colour independent of the presence or absence of grey factors. The resultant relative frequencies to be expected for black, grey, and white colour – that is, 12:3:1 – were noted to the left. The article of 1908 interprets the data under a different assumption to bring the observed absolute frequencies into better accord with the theoretically developed frequencies. It starts from the assumption that black colour results from two factors for black which severally and jointly effect black colour, only their complete absence resulting in white and greyish colours.

Such traces in the register evince that a separate space of symbolic representation had to be opened by Nilsson-Ehle to explore the regime of Mendelian combinatorics in order to 'see' how assumed factors might combine to reproduce the empirically observed distribution of characters. Such distributions, that is, were not simply to be 'seen' from what the register itself presented as data. They were rather developed in a trial-and-error fashion by performing mathematical permutations with symbolical representations in a separate paper space and comparing the results with the data contained in the register. The recording system instituted at Svalöv, however, did not leave much space for such manipulations. This becomes especially clear, when we look at how Nilsson-Ehle's experiment with the cross 0353 x 0668 proceeded: For 1907, the corresponding field-book is not preserved, and the notes on the continued experiment contained in the 1908 field book offer a disappointment. Except for a few notes on the cultivation and development of the plants, it only offers the following dry remark: 'Numbers 272-317 of cross 0353 x 0668 have been handled from a theoretical viewpoint. See separate lists (Korsningsnumren 0353 x 0668 272-317 är bearbetad ur teoretisk synpunkt. se särskilda listor)'. Moreover, Nilsson-Ehle returned to the pedigree method in the third hybrid generation, i.e. the separate cultivation of types selected for a specific, overall character (in this case 'earliness'). This was a move that clearly contradicted Mendelian methodology, which demanded strict renunciation of any kind of selection. Nilsson-Ehle also returned to the old pattern of record keeping: For each parcel in 1906 a taxonomic characterisation of different types (A, B, etc.) was carried out, which also, but not only, and especially not always (namely in those cases, were it did not make a difference), included seed colour. The segregation ratios for seed colour in the third hybrid generation had to be 'distilled' painstakingly from the 46 field book entries descending from the 1903 cross of pedigrees 0353 and 0668, and were anyway, with the low absolute numbers and the previous selection, anything else than trustworthy (see Müller-Wille 2005 for details).

If Nilsson-Ehle saw himself forced to return to the standards of carrying out and recording breeding experiments in place at Svalöv – after all, he was an employee of the experimental station –, or if he hoped to hit upon a stable, promising type combining high yields with winter hardiness in the third generation – in this he admittedly saw himself deceived (Nilsson-Ehle 1924) – is a matter of speculation. It is interesting, however, to see, how each new paradigm of ‚scientific' breeding at Svalöv struggled to establish itself in a preformed context of ‚practical' breeding, with 'scientific' and 'practical' not marking the two poles of an opposition, but rather relative positions on a continuous scale. An illustration from a monograph describing work at Svalöv, which was published in 1912 for the Canadian Seed Grower's Association (Newman 1912, 88), nicely demonstrates how each of the breeding methods developed at Svalöv – mass selection, pedigree breeding, and Mendelian hybridization – presupposed the other, both historically and practically.



Nilsson-Ehle may have mastered Mendelism, but he depended on Nilsson's pedigrees, his own and his assistants' 'breeder's eye', and the skill of the 'unskilled' work-force of women and children employed to cultivate the fields, for the undeniable successes he had in breeding and marketing new cereal strains like Solhvete.

Parcels and register pages were scarce resources at Svalöv – each parcel and each field book entry consumed space, time, and work–, so that each new way of doing or seeing things had to accommodate itself within pre-existing, and mostly seasoned, ways of doing and seeing things. Innovations, that is, could not simply replace traditions, but rather were grafted onto them. Modern science nests within pre-existing practices and technologies, and the relationship between 'theoretical' and 'practical' knowlegde is therefore not a vertical, but a horizontal one. Breeding registers, as I hope to have shown in this essay, provide an excellent source to uncover the conflicts and synergies that arise from this relationship.

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