AN AGRICULTURAL EXPERIMENT IN THE UNPROTECTED SALT MARSH

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1. INTRODUCTION

People first began to settle in the coastal regions of Friesland and Groningen about 600 B.C. The earliest settlements, the so-called *Flachsiedlungen*, still lay at ground level. It was probably as a result of the increased activity of the sea that the inhabitants of this region were urgently compelled, ca. 500 B.C., to raise the level of their dwelling-places, and thus the well-known *terpen* or dwelling mounds arose. Those dwelling-places which were not raised in this way became flooded over and covered by a clay deposit. The rise in level of the *terpen* was not simply the result of the accumulation of refuse: there are clear indications of a deliberate elevation of the dwelling-level. Initially only a few regions were inhabited, such as Westergo, Oostergo, along the Hunze, near Middelstum, on the Fivelboezem and along the Ems (Waterbolk 1972). Later the entire coastal region of the Northern Netherlands became gradually colonised.

The inhabitants of the undiked coastal region were thus obviously exposed to the influence of the sea. Results of botanical research on *terpen* and *Flachsiedlungen* have shown that the natural environment of the inhabitants of the coastal region of the Northern Netherlands was formed by halophytic vegetations (Beijerinck 1929, van Zeist 1974). This could only have been possible if the region became flooded by the sea occasionally. If this had not been the case, then the soil would within a short time have become sweetened as a result of which the halophytes would have disappeared. Until the coastal region was diked, which began about 1000 A.D., the environment of the *terp* dwellers must have been brackish.

The extensive salt marshes would have been almost ideal pasture-land for the cattle of the *terp* dwellers. The drinking-water supply for both people and livestock, for which rainfall was relied upon, could have been a problem in dry summers. One would expect brackish salt marshes to be less suitable for agriculture. Cultivated species are however regularly encountered in ancient settlement sites in the Northern-Netherlands coastal region. These include: *Hordeum vulgare* (six-rowed barley), *Avena sativa* (oats), *Vicia faba* var. *minor* (Celtic bean), *Camelina sativa* (gold-of-pleasure) and *Linum usitatissimum* (flax). It is not yet clear whether *Brassica campestris* (rapeseed) was cultivated or whether the seeds of this plant were collected in the wild (van Zeist 1974).

The mere presence of seeds of cultivated plants in the *terpen* is not in itself indicative of agriculture. Agricultural produce from the farmers of the neighbouring areas of sandy soil could have been obtained in exchange for livestock products. It is however improbable that the farmers on the higher areas of sandy soil could ever have grown enough grain and other crops to supply the needs of the fairly large population of the coastal region. Moreover the plant remains are themselves indicative of agriculture in the coastal region. In the case of flax, gold-of-pleasure and barley not only have the seeds been found but also the remains of threshing, such as capsules and fragments of spike axes. This indicates that these plants were threshed on the spot. If the crops had been imported then only the threshed products, which take up far less space than the unthreshed capsules and ears, would have been transported.

The question arises as to what extent the brackish salt marshes, which became flooded by storm surges, were suitable for agriculture. Small fields of limited extent could have been laid out on the *terpen*, between the dwellings. Agriculture on a somewhat larger scale can only have been practised however on the salt marsh outside the settlements. Bennema (1954, p. 42) reports that a salt marsh becomes generally silted to about 40 cm above mean high water. It is impossible to grow crop plants at this level because of too great a risk of flooding during the growing season. There are however also salt-marsh deposits which are silted up to more than 40 cm above mean high water. Thus, the surface of a marsh bar (Dutch: kwelderwal), the elevated outer margin of a salt marsh, can reach a height of 1.20 m above mean high water (Bennema 1954, p. 46). On these marsh bars, and perhaps also on natural levees along creeks, which are less often flooded, agriculture would be sooner possible.

It had been known for some time previously, that crops can be raised on brackish soils. In the Andijker experimental polder (West-Friesland) both winter and summer crops were raised on a fairly large scale during the season 1928-1929, one year after the land had been drained. In the period from mid-October 1928 until mid-April 1929 the NaCl concentration in the uppermost 20 cm of the soil fell from 14.0 to 3.3 per l of soil-water. During the summer of 1929 in the cultivated part of the polder the NaCl concentration in the layer 5-20 cm deep, which most of the roots occupy, rose to 10 g per l soil-water. In general, good results were obtained with grain crops (wheat and barley), beetroot and potatoes. Pulses on the other hand did rather badly. The winter coleseed, sown in late August/early September, germinated poorly, because the salt concentration in September and early October was too high (Rapporten 1932, pp. 55-59, 225-226).

In the years 1945-1948 van den Berg (1950) compiled crop yield data in areas in the southwest of the Netherlands which in consequence of acts of war had been flooded by the sea in 1944. The inundation with salt water lasted here from a few months to about 1½ years. Van den Berg's study included soils which had been flooded for at least 6 months. Various crop plants turned out to give still reasonable results on salt-containing soils. Summer barley proved to be the most salt-tolerant, followed by fodder-beet, sugar-beet and oats; with regard to salt-resistance, summer wheat, flax and potatoes were in an intermediate position. Pulses appeared to be very sensitive to salt.

Iwersen (1953) has carried out extensive experiments on growing crops in newly-diked salt-marsh land still containing salt in the Finkhauskoog near Husum (Schleswig-Holstein). The aim of that research was not so much to ascertain which crops would still give a reasonable yield on a brackish soil, but rather to discover by which means, including the raising of certain crops, the process of soil-ripening is promoted. According to Iwersen *Brassica napus*, *Brassica rapa*, *Beta vulgaris* and *Trifolium pratense* should be good pioneer species. Although the raising of grain (oats, summer barley and winter wheat) and pulses (peas and broad beans) was dissuaded in the first few years after the enclosure by dikes, these crops already gave reasonable yields under otherwise favourable conditions.

Wohlenberg (1964) mentions that in 1962 the Ülvesbüller Koog, ca. 10 km southwest of Husum, became flooded following a breach in the dike. The winter coleseed, that had stood under salt water for about 5 days, died as a result. Summer coleseed, that was subsequently sown, gave an almost normal yield, although germination stagnated seriously due to a dry period after sowing, which caused high salt concentrations in the uppermost 20 cm of the soil.

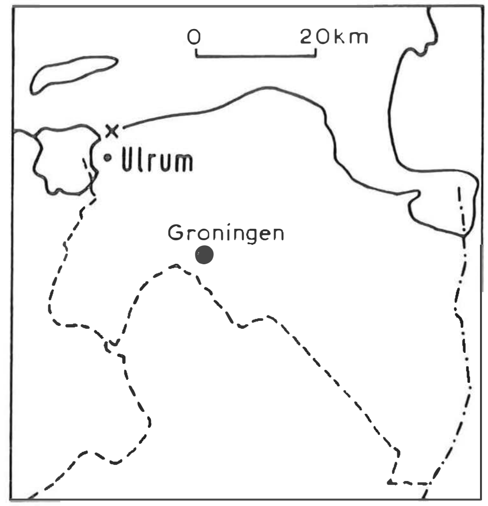
It was first shown by Körber-Grohne (1967, pp. 209-231) that crops can be raised not only in the newly-diked still brackish polders but also in areas still exposed to flooding by salt water. During two successive years on land outside the dikes near Cappelersiel, ca. 25 km north of Bremerhaven, Körber-Grohne raised crops which had been encountered in the Feddersen Wierde, a *terp* dating from the first until the fifth century A.D. Some of the results of this research will be later discussed.

In 1968 barley, flax and horse-bean were grown by T.C. van Hoorn on the undiked salt marsh bordering on the Westpolder, ca. 4.5 km north of Ulrum. The experimental plot, 4 x 6 m^2 in extent, was set up in an area (cadastral Municipality of Kloosterburen, section D no. 1028) used by Mansholt's Veredelingsbedrijf (Plant-breeding firm), Westpolder 8, Ulrum. Insufficient protection against cattle led to an untimely end of this experiment which until then had given satisfying results.

With regard to the possibility of continuing these agricultural experiments, T. C. van Hoorn contacted the Biologisch-Archeologisch Instituut. It so happened that W. van Zeist had already contemplated for several years setting up a small agricultural experiment with crops which had been raised in former times by the *terp* dwellers, but that it had not been possible to realise this plan. It was clear therefore that the experiment begun in 1968 should be continued, this time as a joint project.

During a discussion on March 19th 1969 Ir. U. Mansholt affirmed his willingness to give his complete cooperation. He gave permission to use a new area of salt marsh next to the plot cultivated in 1968. Later this experimental field was somewhat extended, while in addition another small area on the same was included in the experiment.

This research should provide more data on the degree of suitability of various crops for cultivation in the brackish environment of the *terp* dwellers. More information should also be forthcoming in answer to the question as to which part of the unprotected salt marsh was suitable for agriculture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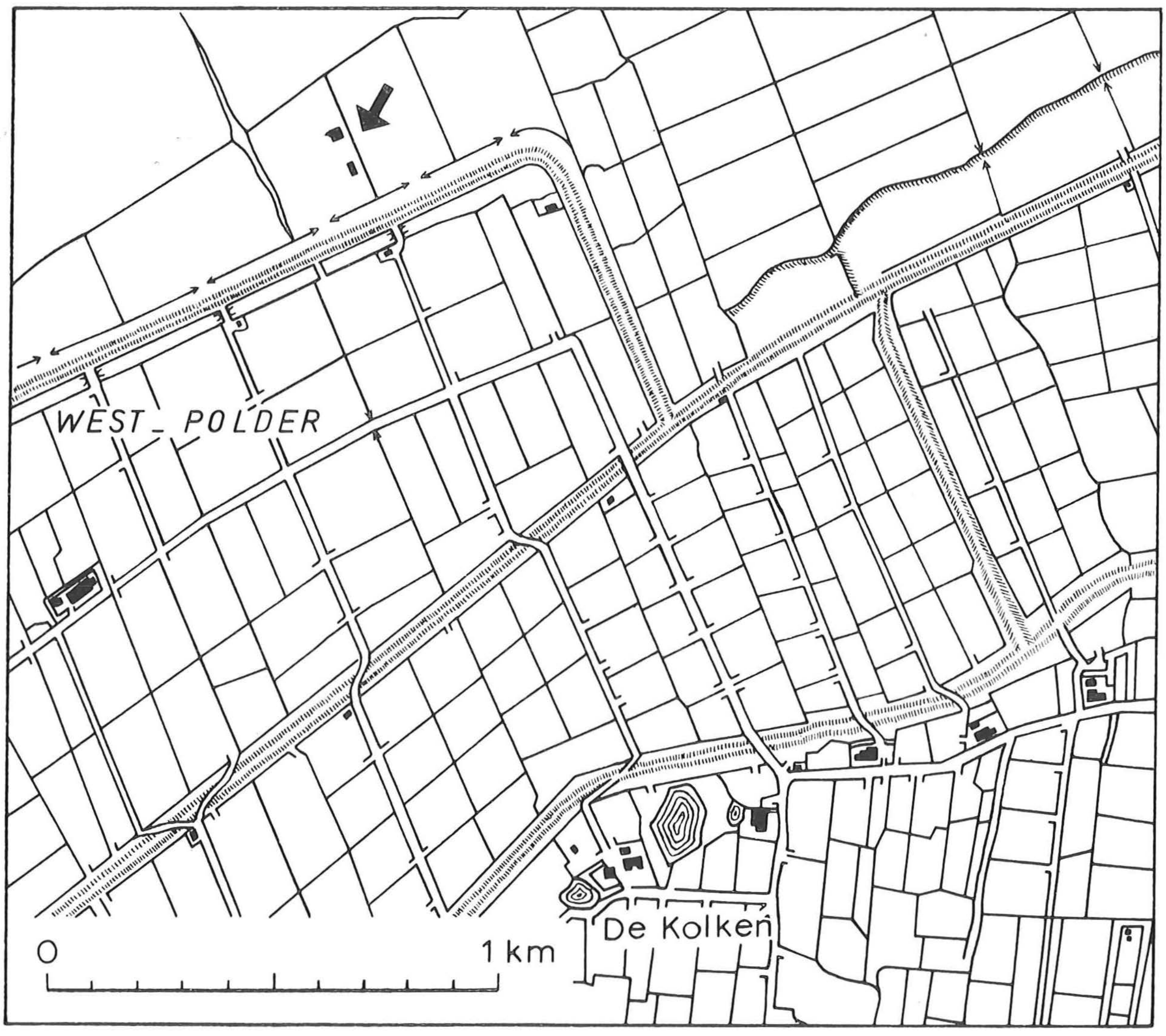
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Fig. 1. Location of the experimental fields (indicated by an arrow) in the undiked salt marsh near the Westpolder.

in former times. By extending the experiment over a number of years, an impression could be gained of the fluctuations in crop yield as a result of weather conditions. These data would at the same time provide information concerning the risk run by the *terp* dwellers of a total or partial crop failure.

As will be further discussed in detail in section 9, the narrow strip of salt marsh near the Westpolder is not completely comparable with the salt-marsh region several kilometres wide along the coast of the Northern Netherlands before this region was enclosed by dikes. A situation such as that near the Westpolder is at the present time however the only possibility for an agricultural experiment on unprotected salt marsh.

In the following report the results over the period 1969-1975 will be dealt with. The experiments will be continued for several more years.

2. LOCATION OF THE EXPERIMENTAL FIELDS

As already mentioned above the agricultural experiment was set up in the unprotected salt marsh lying to the north of the Westpolder (fig. 1). At the level of the experimental fields I and II (see below) the width of the salt marsh is ca. 225 m. On the seaward side the high salt marsh is bordered by a steep erosion cliff ca. 1 m in height. Although not strictly correct, the unprotected salt marsh will be referred to in this report as Westpolder.

Experimental field I was set up immediately east of the small area cultivated in 1968, ca. 10 m from the erosion cliff (fig. 2). This field was originally 12.25 x 10.50 m² in area (fig. 3); later, in 1973, it was extended on the eastern side by 6 m, so that it now measures 18.25 x 10.50 m².

In September 1969 a levelling survey was made. Levels were taken not only of experimental field I and its immediate surroundings but also of a series of points along a line between the field and the dike. The results of this levelling survey are shown

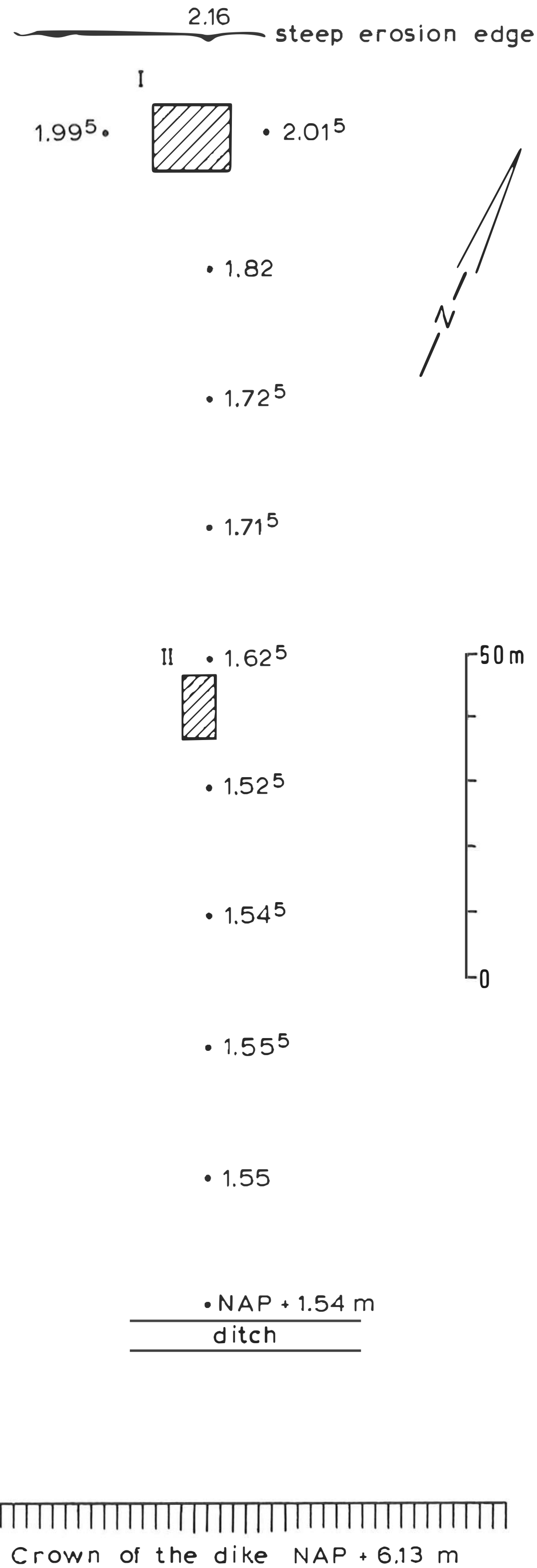


Fig. 2. Heights above NAP (New Amsterdam Ordnance Datum) in the salt marsh near experimental fields I and II.

in figs. 2 and 3. The highest measured point on the salt marsh, near the erosion cliff, is NAP + 2.16 m. Field I lies between NAP + 2.05^5 – 2.14^5 m. Mean high water at the level of the Westpolder is at NAP + 0.96 m. Field I thus lies ca. 1.14 m above mean high water.

Experimental field II, half-way between the dike and the erosion cliff was used during 1970-1972. This small area, measuring 12.50 x 4 m^2 (fig. 9), was situated at NAP + 1.55-1.60 m, thus ca. 0.61 m above mean high water.

The salt marsh is grazed, mostly by sheep though in some years also by young cattle.

3. WEATHER CONDITIONS AND SOIL

Precipitation as well as maximum and minimum temperatures are measured daily at Mansholt's Veredelingsbedrijf. These data for the period March 1st-August 31st in 1969 and subsequent years (in 1972: April 3rd-August 31st) are given in figs. 4, 10-12 and 19-21.

Figures for high-water levels were provided by the Rijkswaterstaat, directies Groningen and Friesland (State Water Boards of Groningen and Friesland), first for Veerhaven-Oort and later for Lauwersoog. Those tides which are higher than NAP + 1.55 and 2.05 m are shown in table 1. During high tides above NAP + 1.55 m the lower-lying field II was completely or partly flooded. Experimental field I, situated at an average height of NAP + 2.10 m, was threatened by tides exceeding NAP + 2.05 m in height.

The soil of field I consists of a very sandy clay, while that of field II consists of clay.

During the first year (1969) samples were taken from experimental field I in the course of the season (fig. 3). The moisture and salt content of these samples were determined by Drs. J. N. Lanting. The results of these determinations are shown in table 2. The moisture content was determined by weighing the sample before and after drying. As a measure of salt content the cloride ion (Cl^-) concentration was determined using a potentiometric method.

4. CROPS GROWN AND METHODS USED

The following crops were grown in the period 1969-1975:

Beta vulgaris (only in 1969). Sowing seed from Mansholt's Veredelingsbedrijf (Plant-breeding firm).

Hordeum distichum. Sowing seed from Mansholt's Veredelingsbedrijf.

Hordeum vulgare. Bigo and Oderbrucker varieties (summer barley). Sowing seed from the Instituut voor Plantenveredeling (Institute of Plant Breeding) at Wageningen and own harvest.

Avena sativa. Sowing seed from Mansholt's Veredelingsbedrijf and own harvest.

Panicum miliaceum. Sowing seed from commercial seedsman.

Triticum aestivum. Sowing seed from Mansholt's Veredelingsbedrijf.

Camelina sativa. Sowing seed from the Instituut voor Plantenveredeling at Wageningen and own harvest.

Linum usitatissimum. Sowing seed from commercial seedsman and own harvest.

Vicia faba var. *minor*. Sowing seed from commercial seedsman and own harvest.

As a general rule seeds were sown in rows. Distances between rows were as follow:

Hordeum	20 cm
Avena	20 cm
Vicia	25 cm
Camelina	10 cm
Linum	10 cm
Panicum	20 cm
Triticum	20 cm

Initially *Camelina* was sown broadcast on occasion. The subdivision of the experimental fields I and II is shown in figs. 3, 8, 9 and 18.

During the period between sowing and harvesting the fields were visited regularly and observations made of the state of the crop with regard to such things as percentage germination, height of plants, time of flowering, etc.

Flax and gold-of-pleasure were harvested by pulling up the plants. In the case of Celtic bean the ripe pods were plucked. Barley and oats were reaped with a sickle; these crops were only pulled

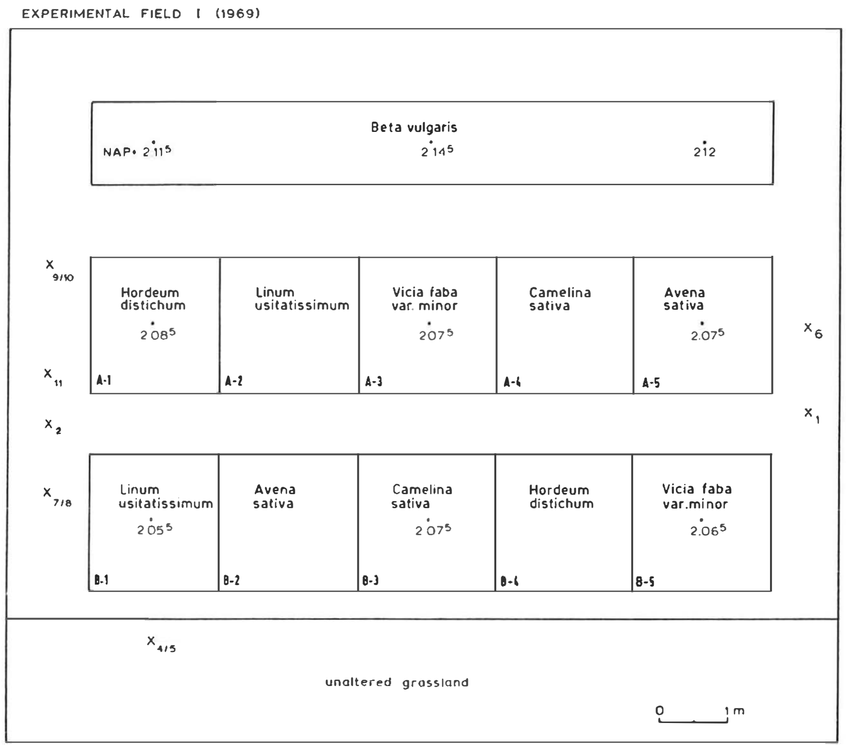


Fig. 3. Experimental field I in 1969 with heights above NAP. The places where samples were taken for salt and humidity determinations (table 2) are indicated with a cross.

up if there were just a few plants or if the plants had remained too short. After drying the crops were threshed at the Biologisch-Archeologisch Instituut, except for the barley and oats, in which case threshing was done at Mansholt's Veredelingsbedrijf.

5. PROGRESS OF THE RESEARCH

5.1. *1969 SEASON*

5.1.1. GENERAL CHARACTERISTICS

In the second half of March a strip of land was ploughed up and subsequently an area measuring 12.25 x 10.50 m² fenced in. The fence, ca. 1 m high, consisted of boards with narrow spaces between. After sowing barbed-wire was also put up above the boards. The fence was necessary primarily to prevent sheep and young cattle from disturbing the experiment. In addition the fence offered some protection against the wind.

The fenced area also included a strip of unploughed land, so that the natural vegetation on this part of the salt marsh could be studied (see 7.1.).

The cultivation plots were set out in two strips of 10 x 2 m² (series A and B). Each series consisted of 5 plots each 2 x 2 m² (fig. 3). Series B was sown on March 28th and series A on April 28th. In early April, 4 rows of sugar-beet were sown to the north of series A. Series A and B were not fertilized. Only the sugar-beets, which will not be further discussed here, were treated moderately with nitrogenous fertilizer.

After sowing nets were spread out over the plots to prevent birds from eating the seeds. In the case of both series the nets were removed about 3 weeks after sowing. Experience has shown that nets with a mesh width of 2 cm were of little effect. Nets of mesh width 0.5 cm were better, though certainly not 100% effective.

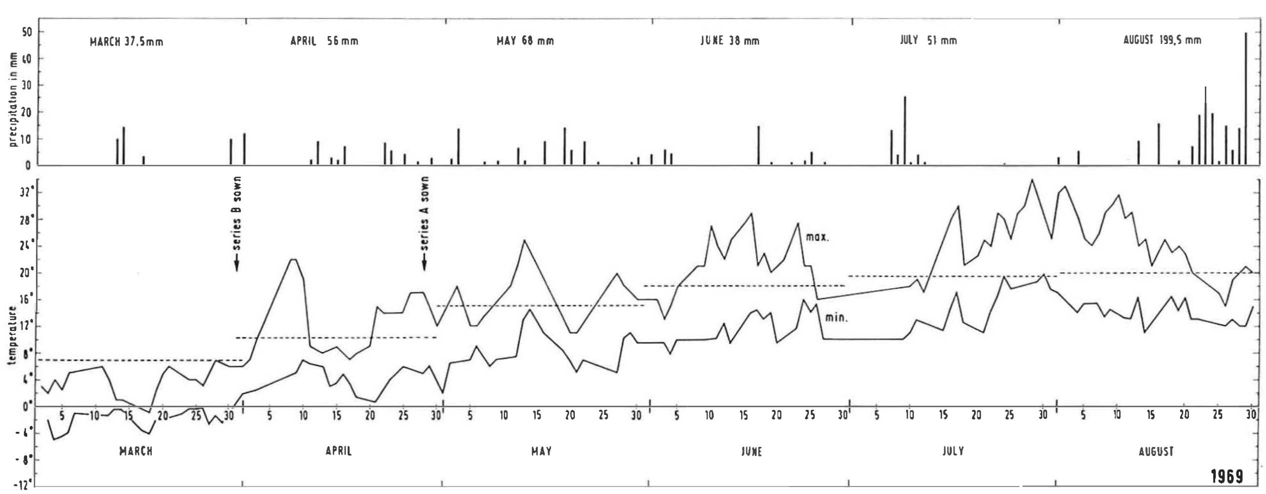
It appears from the temperature data (fig. 4) that during the month of March temperatures were lower than normal. Soon after sowing series B (on March 31st), maximum temperatures rose considerably, to fluctuate about the mean during the rest of April and also throughout May. In both April and May total precipitation was higher than normal. In June maximum temperatures were in general above average, while during that month precipitation was less than average. The second half of July and most of August (until the 20th) were relatively dry and warm. The last 10 days of August were very wet however with normal maximum temperatures. There was a violent storm on July 7th.

The pattern of temperature and precipitation outlined above is reflected to some extent in the moisture content of the uppermost 10 cm of the ground (table 2, see also fig. 3). The sample taken on July 16th thus had the lowest percentage of moisture. The salt concentration, expressed in grams Cl^- per litre of water, is partly dependent on the moisture content of the soil. As a general rule a low moisture content goes together with a higher salt concentration. In addition the quantity of Cl^- per gram of dry soil (the "absolute salt concentration") varied considerably. Instances where this absolute salt concentration was higher at a depth of 20 cm than near the surface can be explained as a result of out-washing. The sample taken on July 16th (no. 11) had a far higher absolute salt concentration than the other samples from near the surface. This indicates differences in salt concentration probably due to the non-homogenous state of the ground. All samples were taken from outside the areas sown. It should be borne in mind when considering the figures shown in table 2 that the NaCl concentration of the Waddenzee is 15-20 g per litre of water, i.e. 9-12 g Cl^- per litre.

During the period from September 1st 1968 until September 1st 1969 there was only one high tide exceeding NAP + 2.05 m (table 1). On February 2nd 1969 a highest level of NAP + 2.45 m was recorded on the tide-gauge at Veerhaven-Oort (the height of the experimental field being NAP + 2.05^5-2.14^5 m).

In order to become acquainted with the weed flora of newly cultivated salt marsh it was decided not to remove weeds. This had no damaging effects on the crops, because weeds only began to develop towards the end of the growing season. These weeds sometimes reached a size of 1 m in diameter (fig. 5). Germination and development of the crops progressed considerably faster with the late-sown series than with that sown earlier. In spite of this the yields of the earlier-sown crops (except for gold-of-pleasure) were considerably greater.

Fig. 4. Precipitation and minimum and maximum temperatures recorded at Mansholt's Veredelingsbedrijf (Plant-breeding firm) in the Westpolder from March 1st to August 31st 1969. The dashed lines indicate the mean maximum temperatures for the months concerned. For the region in which the Westpolder is situated the following mean monthly precipitations are reported: March ca. 35 mm, April ca. 40 mm, May ca. 45 mm, June ca. 50 mm, July ca. 80 mm, August ca. 85 mm. The mean temperatures and precipitations, for the period 1931-1960, are after Kaart van Nederland, Plates V-3 and V-1.



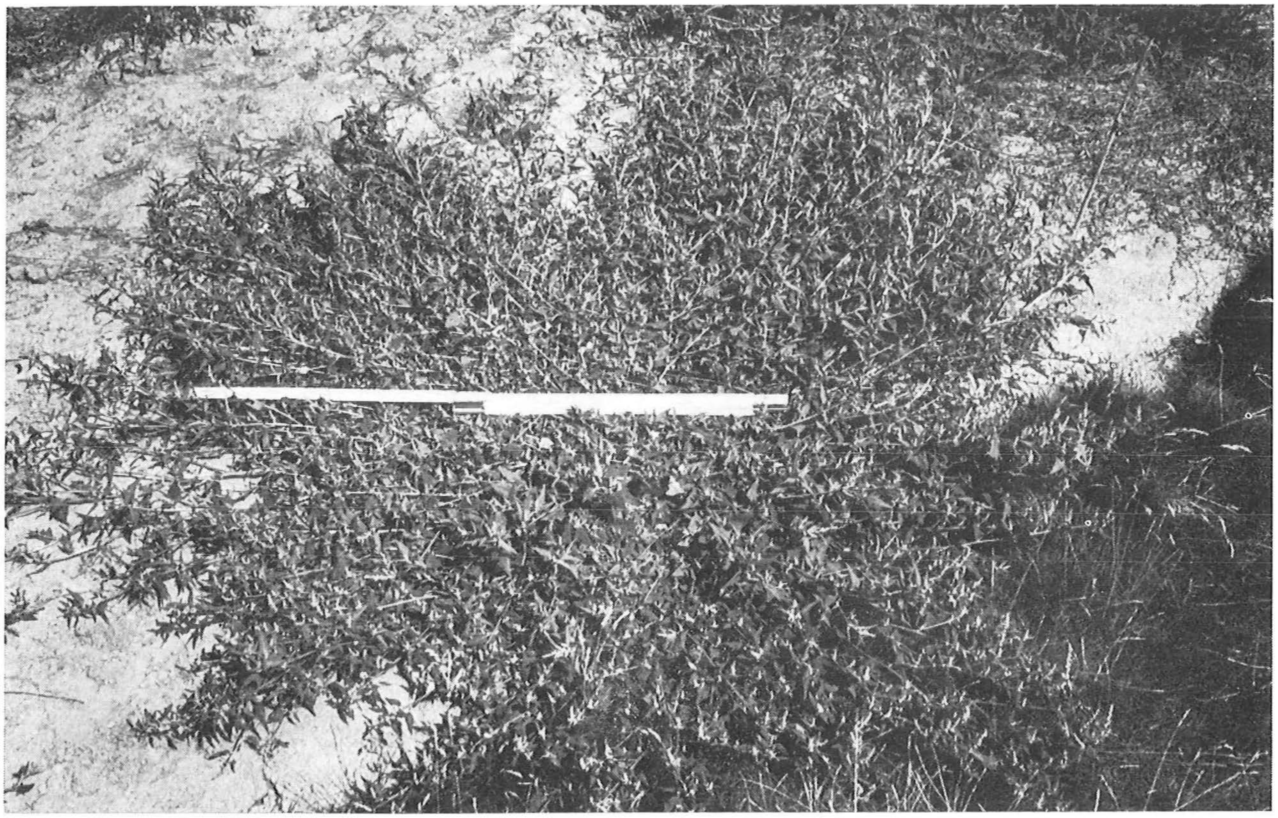


Fig. 5. Vigorously developed specimen of *Atriplex hastata* in field I (August 9th 1969).

The development of crops grown in series A and B will be dealt with separately for each species. The crop yields for 1969 and subsequent years are given in table 3.

5.1.2. LINUM USITATISSIMUM

On plot I-B-1, ca. 70% of seeds had germinated within 4 weeks after sowing (April 28th). Development was good, though growth pattern was rather variable. On June 13th the tallest plants were 40 cm high and the shortest 10 cm. The flax was in flower on June 23rd when its maximum height was 60 cm. In the storm of July 7th a number of plants were blown over. The flax was pulled up on July 24th (fig. 7c).

On plot 1-A-2, ca. 70% of seeds had germinated within 2½ weeks after sowing (May 14th). Growth was also irregular here. This crop was flowering in abundance on July 2nd and was harvested on July 31st.

5.1.3. CAMELINA SATIVA

On plot I-B-3, 25% of seeds had germinated by April 21st, 3 weeks after sowing. The seedlings were only 5 cm high up until 8 weeks after sowing, after which time growth was more rapid. On June 23rd the plants had reached a maximum height of 50 cm and were branched, with some already in seed and some still in flower on top (fig. 6a). Flowering was mostly over by July 2nd and on July 24th the plants were harvested.

In I-A-4, ca 80% of seeds germinated within 2½ weeks after sowing. After 4 weeks the seedlings were up to 3 cm high. The plants were very crowded together which resulted in slow development of some plants. This plot was flowering in abundance 8 weeks after sowing. The storm of July 7th had no damaging effect. This crop was harvested 13½ weeks after sowing.

5.1.4. VICIA FABA VAR. MINOR

On plot I-B-5, the seedlings came up 3 weeks after sowing. By May 14th each seedling had 2 small leaves. By June 13th one plant, 17 cm high, was in flower. One week later the crop was in flower over the whole plot (fig. 6c). Many plants were blown over during the storm of July 7th. Most of the pods were gathered on August 9th, the rest on August 18th. Each pod contained 2-4 beans. From the beginning of July onwards damage was inflicted by aphids.

In I-A-3, ca. 90% of seeds had germinated by May 27th, 4 weeks after sowing. On a subsequent inspection all seedlings appeared to have been pulled up by birds.

5.1.5. HORDEUM DISTICHUM

On plot I-B-4, ca. 40% of seeds had germinated by April 21st. During the growing period the leaves or their tips turned yellow. By May 27th only ca. 5% seemed to be growing reasonably well. Harvesting was on August 9th.

In I-A-1, ca. 70% of seeds had germinated by May 15th. On July 2nd the few surviving plants were beginning to come into ear, although these often remained in the uppermost leaf. Harvesting was here also on August 9th.

5.1.6. AVENA SATIVA

On plot I-B-2 only a few seedlings were visible at 3 weeks after sowing. There were many empty husks (caused by skylarks?). Germination was not more than 5%. On June 23rd the remaining plants were up to 40 cm high. These plants were blown awry during the storm of July 7th. Harvesting was on August 9th. Few grains per ear.

On plot I-A-5, 30% of seeds had germinated within 2½ weeks after sowing. Yellow leaves soon appeared. Damage due to birds still continued. The crop looked rather mediocre. Harvesting on August 9th.

5.2. 1970 *SEASON*

5.2.1. GENERAL CHARACTERISTICS

On account of the fact that no more sugar-beet was grown, the subdivision of experimental field I was otherwise than in 1969. This time there were two series of plots measuring 2 x 3.70 m^2 (fig. 8). In order to investigate the effect of manuring, plots in series A were spread with dried cow-dung before sowing from 1970 onwards. Both series of field I were sown on March 26th. To prevent damage by wind, corrugated plastic sheets 30 cm high were placed between the plots.

Meanwhile experimental field II, measuring 12.50 x 4.00 m^2, was set up, This area was sown on April 15th. Here also both manured and unmanured series were set up; each plot measured 1.5 x 2.0 m^2 (fig. 9). This field was surrounded by a fence of barbed wire and rush-matting.

In March and April the temperature remained well below average: low maximum values and at night up to 10°C of frost (fig. 10). On April 29th the salt marsh became flooded during a violent storm. The wooden fencing around field I was swept away and the wind-breaks, wrenched out of the ground, caused severe damage to the crops. Part of the young crop was washed away by the water. The lower-lying field II was protected from severe damage by the rush-matting which moved to and fro together with the water.

According to the data provided by the State Water Board for Friesland a maximum high-water level of NAP + 2.30 m was recorded at Lauwersoog on April 29th (table 1). However the upper limit of the tidal drift deposited against the Westpolder dike indicates that the water on the undiked salt marsh must have reached a level of at least 4 m above NAP.

In the course of the season many seedlings died or turned yellow. Re-sowing had little effect. The halophytes, on the other hand, developed vigorously. The increased salinity caused by the flood was reinforced by the fact that in May and June temperatures were on the high side, while in addition both months were exceptionally dry (fig. 10): 14.5 mm rain in May (normally 45 mm) and 17.5 mm in June (normally 50 mm).

Various weeds increased so abundantly that it was decided in mid-September to start weeding. The extent of weed cover was 80-90% in experimental field I and 50% in field II. During weeding a great many pupae of *Agrotis exclamationis* (an owlet-moth) were found.

5.2.2. LINUM USITATISSIMUM

Flax had germinated in field I (A-2 and B-1) by April 25th, about 4 weeks after sowing, and on II-1 by April 30th. Several days after the flood of April 29th the seedlings on I-A-2 still looked reasonably healthy, while those on plot I-B-1 were already dead. On May 8th the seedlings in field II were also dead; on I-A-2 only those plants which stood on the north side were alive. On May 19th sowing was repeated with sowing-seed from 1969. This had some positive result and by mid-July the new plants were 10-15 cm high. No harvest.

5.2.3. CAMELINA SATIVA

Seedlings on plots I-A-4 and I-B-3 had come up by April 15th, almost 3 weeks after sowing, and on II-3 by April 25th. On April 29th part of the crop was washed away with soil and all. At the beginning of May there were only a few plants left. Sowing was repeated on May 19th. By June 4th only in I-A-4 were there about 10 plants left standing. These flowered in mid-June and were ripe at the end of June. Almost nothing came up from the second sowing. The few plants which did manage to develop were not harvested until September 30th.

5.2.4. VICIA FABA VAR. MINOR

The beans in I-A-3 and I-B-5 began to come up on April 25th. On May 5th it appeared that the beans which had germinated early had been killed by the flood, while those which had germinated afterwards were doing reasonably well. On plot II-5 a few plants had germinated by May 5th, of which only one remained by the beginning of June. By mid-July there were still several dozen bean plants, each with 1-6 pods, growing in field I. A few plants sprouted again at the base.

5.2.5. HORDEUM VULGARE

Summer barley (Oderbrucker and Bigo) was sown in 1970. It concerns here lax-eared forms of six-rowed barley, which are also indicated as four-rowed barley. On plots I-A-1 and I-B-4 the barley had germinated by April 25th, about 4 weeks after sowing, and was in some places already up to 5 cm high. Some damage was caused by birds. In II-4 some barley (Bigo) germinated at the beginning of May. The plants in field I had yellow leaves at the beginning of May; the crop in I-A-1 looked healthier than in I-B-4. By the end of May the barley seemed to have hardly grown any further. In the course of July the crop deteriorated further (fig. 7d). In II-4 all plants were dead by the end of May.

5.2.6. AVENA SATIVA

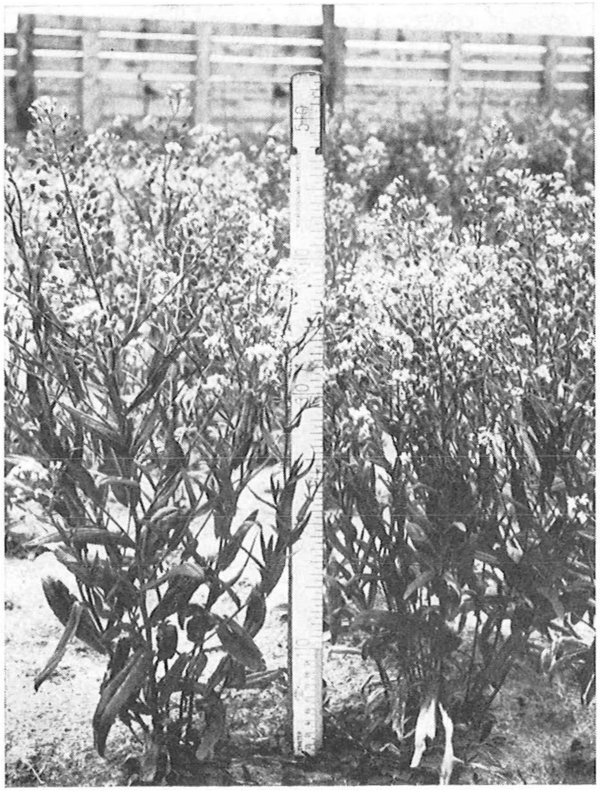
The oats in I-A-5 and I-B-2 came up by April 25th; on the latter plot there was some damage due to birds. On May 5th, after the flood, the plants were yellow and in I-B-2 many had disappeared. At the beginning of June one-third of I-A-5 was still vegetated, but a much smaller fraction of I-B-2. On June 20th ears appeared in I-A-5, the crop then being 40-50 cm high. In mid-July the oats in I-A-5 began to ripen; in I-B-2 there were hardly any plants left.

The oats in II-2 germinated to a very limited extent and by the beginning of June this plot was completely bare.

5.3. 1971 *SEASON*

5.3.1. GENERAL CHARACTERISTICS

During the winter months the wooden fence was completely swept away: as can be seen from table 1 high-tide levels exceeded NAP + 2.05 m eight times during the period from the beginning of October 1970 until mid-March 1971. After the fence had been repaired, both experimental fields were sown on April 15th. The nets were removed on June 14th. Weeds were removed from field I; no weeds were present in field II. In mid-July field I was completely destroyed by young cattle that broke through the fence. A week later the same fate befell field II.



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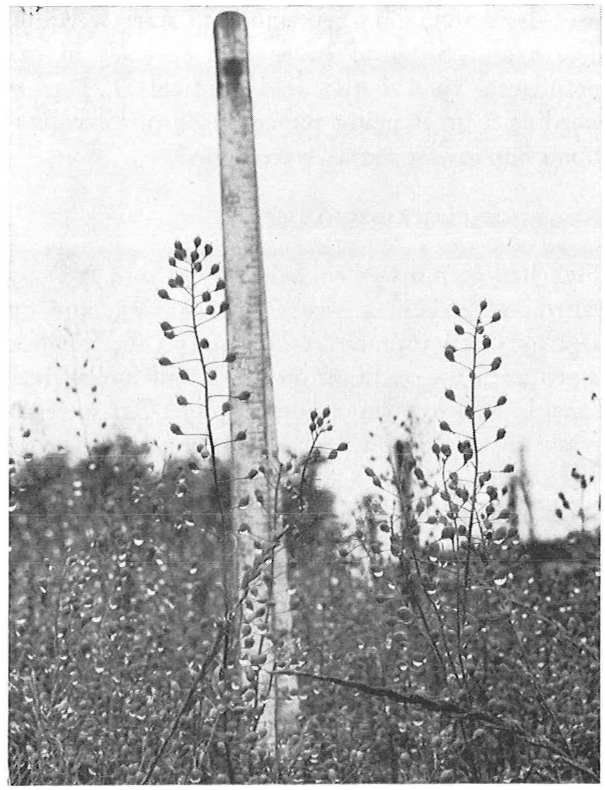


b

c

d

5.3.2. LINUM USITATISSIMUM

By June 8th, about 8 weeks after sowing, about 70% of seeds in I-A-5 and about 60% of seeds in I-B-4 had germinated. Germination was very limited on plot II-3. In I-A-5 and I-B-4 buds began to appear at a height of ca. 10 cm. By the beginning of July the flax appeared to have grown very quickly, up to ca. 50 cm high, at which stage many plants flowered. In II-3 development was poor. No harvest due to destruction by cattle.

5.3.3. CAMELINA SATIVA

In I-A-2 and I-B-1 the first seedlings of gold-of-pleasure appeared on May 14th, 4½ weeks after sowing. By mid-June about 30% of seeds had germinated in both plots. Some plants had shot up and bore flower-buds. On June 24th plant height varied from 6 to 38 cm. The plants developed well until mid-July, especially in I-A-2.

In II-5 the seedlings were up to 3 cm high by June 24th. On July 5th there were 10 plants 5 cm high.

5.3.4. VICIA FABA VAR. MINOR

By one month after sowing a few beans had germinated in I-A-1 and I-B-3. By mid-June germination in both plots was 70-80% and young plants were up to 10 cm high. At the beginning of July the biggest plants (ca. 30 cm high) began to flower. In II-2 a few beans germinated in early June, of which 3 were left over by mid-June. By the beginning of July the number had again increased to about 25.

5.3.5. HORDEUM VULGARE

The variety Bigo was sown in both experimental fields. The barley began to germinate in I-A-4 and I-B-2 one month after sowing. Germination was 70-80% successful, after which the crop grew reasonably well despite yellowing of tips. The barley in I-A-4 was generally taller than in I-B-2. On the latter plot the plants had much yellow foliage. At the beginning of July the plants began to come into ear.

In II-1 the first seedlings were visible on May 23rd. By June 14th 10% of seeds had germinated and the plants were up to 5 cm high. By mid-July the barley on this plot was up to 30 cm high and had many yellow leaves.

5.3.6. AVENA SATIVA

Some oats had germinated in I-B-5 by May 14th, one month after sowing. At the end of May the oats began to die and by the beginning of June there was none left.

5.4. 1972 *SEASON*

5.4.1. GENERAL CHARACTERISTICS

During the period from the beginning of October 1971 until the end of March 1972 experimental field I was flooded three times, and the lower-lying field II far more often (table 1). On March 29th the fields were sown, after plots I-A and the eastern half of field II had been treated with dried cow-dung. Both April and May were wetter than usual (fig. 12): 70.5 mm rainfall in April and 144.5 mm in May, as compared to normal values of 40 mm and 45 mm respectively. Despite the exceedingly heavy rainfall on May 14th there was no evidence of damage inflicted by water. On May 28th experimental field II was flooded by a high tide. After harvesting the weeds were mown using

Fig. 6.
a. Flowering *Camelina sativa*, plot I-B-3 (June 23rd 1969).
b. Fruiting *Camelina sativa*, plot I-B-5 (July 24th 1972).
c. Flowering *Vicia faba* var. *minor*, plot I-B-5 (June 23rd 1969).
d. *Vicia faba* var. *minor* with pods, plot I-B-2 (July 24th 1972.)

a scythe to prevent seed formation.

5.4.2. LINUM USITATISSIMUM

On plots I-A-4 and I-B-3 the flax germinated 2 weeks after sowing and developed well throughout April. At the end of May the flax in I-A-4 made a better impression than that in I-B-3. On June 27th the flax in I-A-4 appeared to be suffering from a late attack of thrips (blighted buds). By the first week of July flowering of flax was almost over. Some of the plants recovered from the thrips. The flax in I-A-4 remained slightly ahead of that in I-B-3. On August 14th the flax on plots I-A-4 and I-B-3 was harvested.

The flax on plot II-4 had germinated well by April 19th, but died in the course of May.

5.4.3. CAMELINA SATIVA

During the sowing in field I many gold-of-pleasure seeds blew outside the rows. Within two weeks after sowing (April 11th) the first seedlings came up. Only a moderate number of seedlings came up however in I-A-1 and I-B-5. On April 26th these plots were re-sown. This second crop came up very well at the beginning of May. On May 30th the first crop was 20 cm high, and the second crop 5 cm. The first crop was in flower on June 12th. By the end of June the plants from the first sowing were up to 70 cm high, and those from the second sowing up to 50 cm. Fruit-setting was good (fig. 6b) and the crop was harvested on August 7th.

In II-1 germination was rather good, but by the middle of May only 5% remained. By mid-June there were only three plants of 25 cm on this plot, the rest being shorter.

5.4.4. VICIA FABA VAR. MINOR

On April 19th, 3 weeks after sowing, the beans began to germinate. By mid-June the beans in experimental field I were up to 40 cm high; the state of the crop in I-A-5 seemed somewhat better than that in I-B-2. At the beginning of July, at an average height of 80 cm, the plants were in flower, while at the bottom fruit-setting had already begun (fig. 6d). After flowering the beans were 60-120 cm high. The beans were harvested after mid-August. No nodules (associated with nitrogen fixation) could be found on the roots.

On plot II-3 ca. 30% germination occurred. By mid-June there were 18 plants still remaining (up to 14 cm high). The beans on this plot eventually reached a height of up to 30 cm, but gave no yield (fig. 14).

5.4.5. HORDEUM VULGARE

On March 29th the variety Bigo was sown. By April 11th some of the barley in fields I and II had germinated. On account of damage due to birds the variety Oderbrucker was sown in addition. In I-A-3 and I-B-1, 50-80% was eaten up by birds, despite the nets. At the end of May the barley in I-B-1 showed several yellow tips. In July the plants were over 1 metre high (fig. 7a). In the long barley some of the plants were eaten up by young goats which had crawled under the fence. The crop was harvested on August 14th (fig. 15).

In II-2, 80% germination occurred (fig. 16). At the end of May the barley here began to turn yellow. On July 6th the plants, at a height of 30-50 cm, were in ear (fig. 17). Harvesting was on August 7th.

5.4.6. AVENA SATIVA

Three weeks after sowing the oats germinated in I-A-2 and I-B-4. By mid-May ca. 90% had come up. On both plots the oats were 30 cm high at the end of May and 70 cm high at the end of June. In July the crop grew up to a height of 120 cm and at the end of July it began to ripen (fig. 7b). The oats were harvested on August 14th.

In II-1 the oats germinated 2 weeks after sowing. By mid-May ca. 80% had germinated. The plants quickly turned yellow; this was reinforced by the flood of May 28th. The plants attained a height of 30-50 cm. The ears were poorly developed.

5.5. *1973 SEASON*

5.5.1. GENERAL CHARACTERISTICS

From 1973 onwards experimental field II was abandoned due to poor harvest results. Field I was extended eastwards with two lots of 3 plots each measuring 2 x 3.70 m^2. The new plots were to demonstrate any effects of newly-reclaimed salt marsh with respect to the old plots. In addition the assortment of crop plants was extended to include *Triticum aestivum* (bread wheat) and *Panicum miliaceum* (broomcorn millet). For the subdivision of the enlarged experimental field I see fig. 18.

On March 13th the crop was sown. Storms and flooding on April 2nd and 3rd ruined the cultivated plots. Most of the seeds were washed away with the soil. Re-sowing on April 24th had not resulted in any germination by May 8th. After that cattle broke through the fence and devastated the plots. The experiment for 1973 had to be given up.

5.6. *1974 SEASON*

5.6.1. GENERAL CHARACTERISTICS

In November and December 1973 field I was flooded many times, thereafter no more. Before sowing a sturdy fence of concrete posts and wire-netting was constructed. The soil structure of those plots in cultivation since 1973 was clearly different to that of the older plots. The lumps of sod were persistent and difficult to break up. Sowing took place on April 10th.

Temperatures in April were clearly higher than normal, while it was also very dry throughout that month. During the other months precipitation was normal. May was on average too cold (fig. 20).

5.6.2. LINUM USITATISSIMUM

The first seedlings could be seen on plot I-B-3 on April 22nd, 12 days after sowing. At the beginning of June the flax had evidently developed reasonably well; furthermore there were many small plants as well. On June 21st the flax began to flower (at a height of 40 cm). In the first week of July all plants came into seed. In the north-eastern corner of I-A-3 damage was sustained (due to thrips?). The flax was pulled up on August 7th.

5.6.3. CAMELINA SATIVA

On April 22nd the gold-of-pleasure had germinated well in I-B-5, though moderately to poorly in I-A-5. At the beginning of June the young plants had yellow and red leaves. The crop in I-B-5 remained in better condition than that in I-A-5. Fruit-setting began by June 21st and a week later all plants were in seed (at a height of 40-50 cm). On August 1st the crops on both plots were harvested.

5.6.4. VICIA FABA VAR. MINOR

Celtic beans were grown on three plots, namely I-A-4, I-A-8 and I-B-4. On April 22nd it appeared that many beans in I-B-4 had rotted in the ground. At the beginning of June in all plots there were some bean plants among orache (*Atriplex*). At the beginning of July these beans had grown to a height of ca. 30 cm and in mid-July they were in flower. The pods appeared at the beginning of July and were later attacked by aphids. The pods were harvested on September 11th. As a result of a misunderstanding the weight of the threshed beans was not determined; the yield was in any case low ("less than the input").

5.6.5. HORDEUM VULGARE

Barley was sown in I-A-2, I-A-7 and I-B-2. By two weeks after sowing plants had already come up. Damage was caused by birds despite the nets. At the beginning of June the barley was yellow here and there. In mid-June the barley in I-A-2 looked better than that in I-B-2, though later this difference became levelled out. At the end of June the barley came into ear at a height of 40-70 cm (shorter than in 1972). On August 1st it was clear that the almost ripe barley had been fed upon by animals (birds?), and two weeks later no harvesting was possible any more.

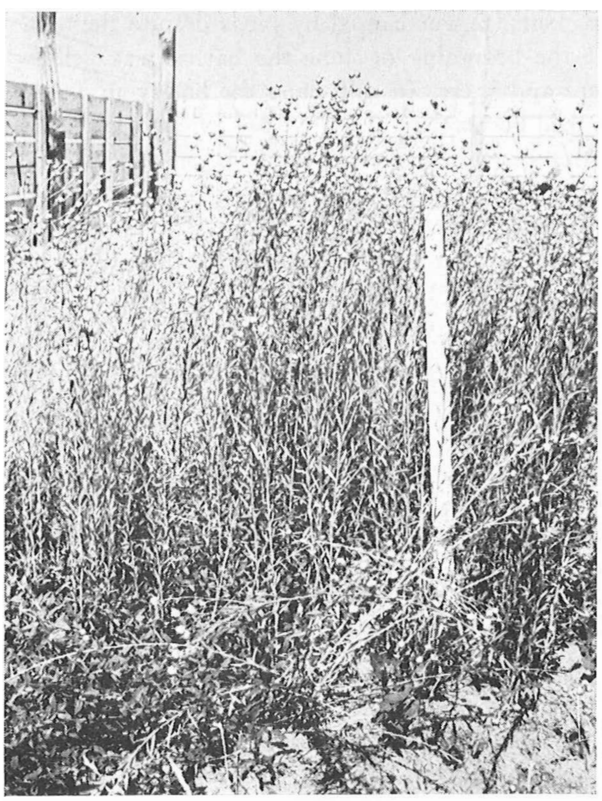
5.6.6. AVENA SATIVA

This crop too was sown in three plots: I-A-1, I-B-1 and I-B-8. On May 3rd, 3½ weeks after sowing, it was evident that a great deal of the oats had been grubbed out the ground (by larks?). Development was poor, and in July there were only 20 plants present in I-A-1, 5 in I-B-1 and 20 in I-B-8. In the first week of August the few ears of oats were eaten bare (by birds?).

a

b

c



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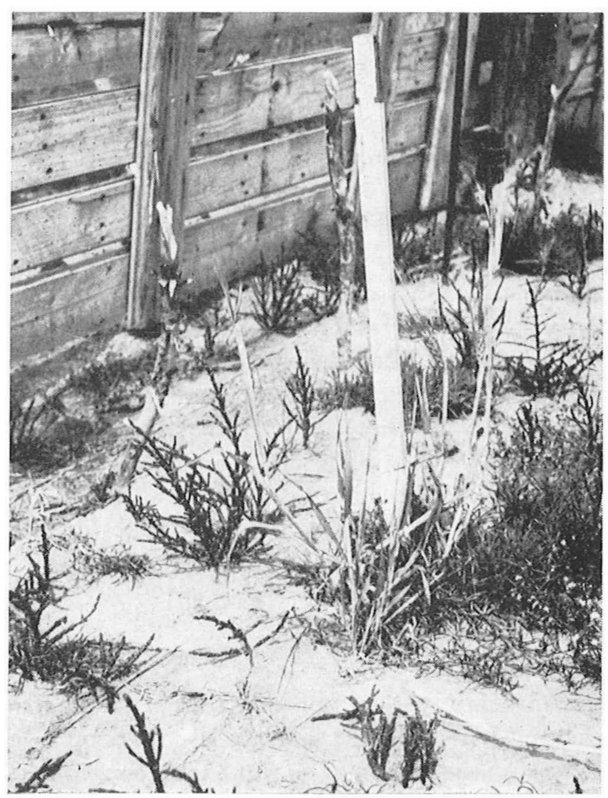


5.6.7. TRITICUM AESTIVUM

One plot (I-B-6) was sown with this crop. Germination and growth of the young plants were poor. In 1974 there were a few scattered plants among many weeds. No harvest.

5.6.8. PANICUM MILIACEUM

One plot too (I-B-7) was sown with millet. It became evident that the sowing-seed had contained different species, including *Panicum miliaceum*, *Setaria italica* and *Echinochloa crus-galli*. The crop became overgrown by weeds. No harvest.

5.7. *1975 SEASON*

5.7.1. GENERAL CHARACTERISTICS

In the winter of 1974-1975 the experimental area became flooded several times (table 1). After sowing on April 18th there was heavy rain for 12 hours. The summer was warm and dry; temperatures in June, July and August were considerably above average. Precipitation in June was half the average amount, and that in August only one-third (fig. 21).

5.7.2. LINUM USITATISSIMUM

In addition to the white-flowered flax grown up until this time (in I-A-4 and I-B-4), blue-flowered flax was now sown, on one plot (I-A-6). Since the seeds of the blue-flowered flax were more than one year old, 50% more was sown than the other (white-flowering) variety. Throughout the whole season the blue-flowered flax remained behind the other flax with respect to stem height. This year the thrips stayed away. The flax was pulled up on August 4th.

5.7.3. CAMELINA SATIVA

As usual the gold-of-pleasure (in I-A-1 and I-B-1) developed rather slowly at first and then suddenly grew rapidly. The gold-of-pleasure was frequented by humble bees and by a species of *Anthophora*. A kind of mildew appeared, but the crop harvested on July 23rd was very homogeneous and gave a very good yield.

5.7.4. VICIA FABA VAR. MINOR

Beans were dibbled in three plots. The beans developed well and began to flower on June 20th. In the first week of July flowers and fruits were present. Aphids appeared in mid-July in I-B-5, and later in I-A-5 and especially in I-A-7, where part of the crop was completely ruined. When the plants were pulled up at the end of August, root nodules were now present. Despite the aphid attack the crop was the best so far (table 3). The plants were shorter than in 1972 (also a good harvest): 90 cm as compared to 120 cm in height. In 1975 the number of pods per plant was very high.

Fig. 7.
a. *Hordeum vulgare* (Bigo variety), plot I-B-1 (July 24th 1972).
b. *Avena sativa*, plot I-B-4 (July 24th 1972).
c. *Linum usitatissimum* with capsules, plot I-B-1 (July 16th 1969).
d. One specimen of *Hordeum vulgare* amidst halophytes on plot I-A-1 (September 12th 1970). The field was flooded by the sea on April 29th 1970.

5.7.5. HORDEUM DISTICHUM

In 1975 two-rowed barley was sown on three plots. The crop remained very short, in addition to which the ears often stayed in the uppermost leaf. When the crop began to ripen, it became eaten up by animals, as had often happened before, to an extent varying from 10 to 50%. The barley was harvested on August 5th.

5.7.6. AVENA SATIVA

The three plots of oats yielded a homogeneous crop, that developed evenly and was harvested on August 8th.

5.7.7. TRITICUM AESTIVUM

The number of wheat plants (I-B-7) was small in 1975 too. These tillered vigorously however, so that a small harvest was obtained after all.

5.7.8. PANICUM MILIACEUM

The broomcorn millet (I-B-8) developed poorly in 1975 too. In contrast to 1974 the crop now gave a small yield.

6. GROWTH AND YIELD OF THE CROPS

6.1. *INTRODUCTION*

For the comparison of the yields of a crop in successive years, on the manured and unmanured plots, two quantities can be used, namely the ratio between harvested crop and amount of seed sown, and the yield per unit surface area. The yields from the experimental plots are calculated per hectare. We could also have chosen a square metre or some other unit of surface area, but the yield per hectare is the most usual in agriculture. The data on amount of seed sown and crop harvested, the yields per hectare and the yield/input ratios are given in table 3. Since this table is rather difficult to survey at a glance on account of the large amount of data, some of the figures are brought together in table 4.

It is necessary to exercise caution in the interpretation of both the yield/input ratios as well as the yields per hectare. For example in 1969 plot I-A-4 yielded an estimated 840 kg gold-of-pleasure seeds per ha and plot I-B-3 only 390 kg. Yet in both cases the yield/input ratio was approximately the same. Clearly too little was sown on plot I-B-3. On the other hand, a hyper-optimal seed input does not increase the total yield (rather the opposite would be expected on account of competition), but the yield/input ratio is decreased.

6.2. *CAMELINA SATIVA*

This crop gave comparatively the best result, i.e. a yield 25.5-57.7 times as great as the seed input. With regard to the yields per hectare, the highest and lowest yields differ approximately by a factor of 2. Here the yield from plot I-B-3 in 1969 has not been taken into consideration (see 6.1.). The relatively uniform harvests in the rather extreme environment indicate that this crop is not very sensitive to weather conditions. The capacity of gold-of-pleasure to branch considerably in an open stand of this crop contributes to a levelling-off of the harvest results: in this case the reduction in the number of plants is compensated for by the greater number of seeds per plant.

Manuring had little or no effect on the yield, as is clearly evident from table 4. In 1972 and 1974 the crop developed better on the unmanured plots, while in 1975 it was the manured plot which gave a somewhat better yield. The average yield per ha calculated for the years 1969, 1972, 1974 and 1975 amounts to ca. 1000 kg, which is slightly less than the figure of 1200 kg given for the inland crop. One can conclude that gold-of-pleasure must have been a reliable crop for the *terp* dwellers.

6.3. *LINUM USITATISSIMUM*

For *Linum* the highest yield calculated per ha (1295 kg) was about 3 times greater than the lowest (390 kg). The ratio between harvest and seed input is far less favourable than with gold-of-pleasure. The flax was several times attacked by thrips (*Thrips linarius*). The flax cultivated is the so-called fibre flax, that has a lower seed-yield than the so-called oil flax. For inland crops a seed harvest of ca. 1000 kg per ha is given for fibre flax and double this quantity for oil flax.

A good seed harvest was obtained in 1975. In that year, in addition to the white-flowered variety cultivated up until then, an "old-fashioned" blue-flowered land variety was sown (I-A-6). There is no significant difference in yield apparent between the white- and blue-flowered flax. For flax too the average yield per ha calculated for the years 1969, 1972, 1974 and 1975 (845 kg) is somewhat less than the figure given for inland crops (1000 kg). The effect of manuring is not very noticeable in the case of flax either. In the years 1972, 1974 and 1975 the yields on the manured plots were slightly higher than on those left unmanured. Several days after the flood in 1970, the seedlings on the manured plot appeared to be in reasonable condition, while those on the unmanured plot were already dead. Furthermore in 1972 the crop on the manured plot made a better impression than that on the unmanured plot, though this did not lead to a significant difference in yield.

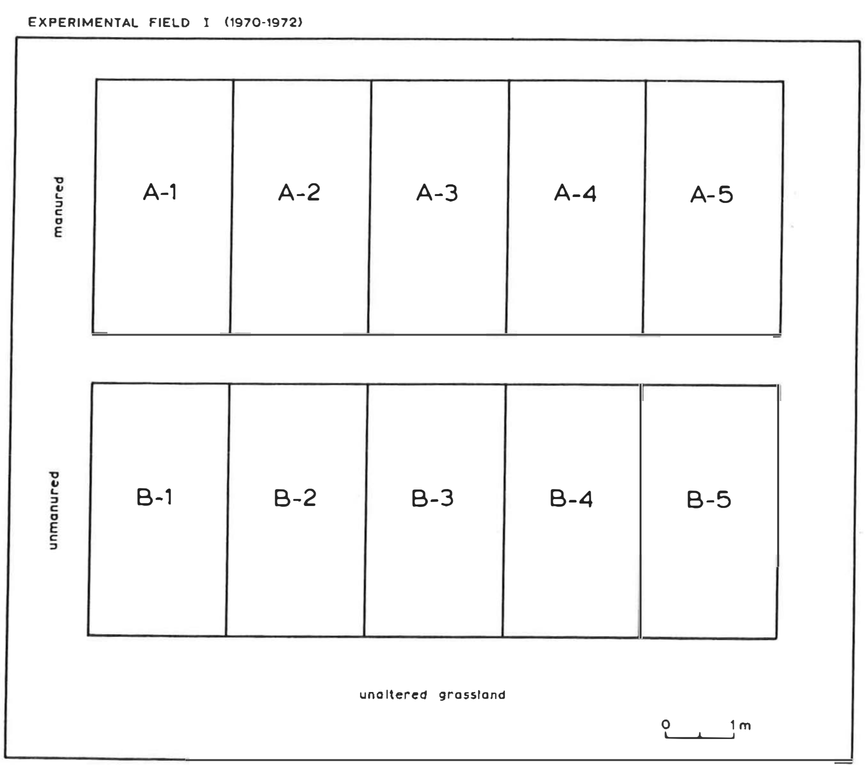
Finds from the *terpen* indicate that the flax fibres were certainly also important. We do not know whether the flax was grown by the *terp* dwellers mainly for the fibres or for the seed. The quality of the fibres from the flax grown in brackish soil has not been investigated. In good years the plants attained a height of 90 cm, which at least guarantees fibres of sufficient length.

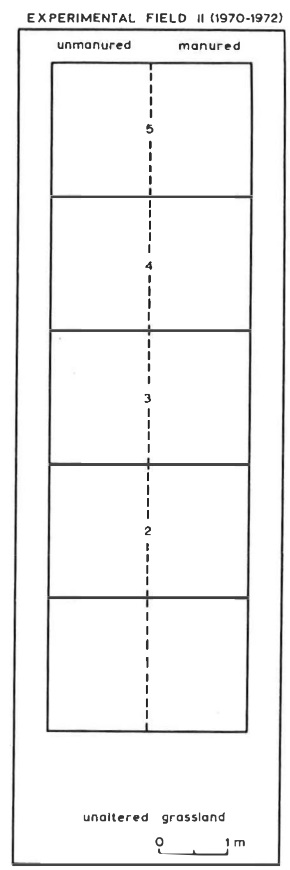
6.4. *VICIA FABA VAR. MINOR*

The experiment in the Westpolder has (again) clearly shown that Celtic beans can be grown with a reasonable chance of success on slightly brackish soil. Under favourable conditions even good harvests can be obtained. The yield of ca. 3800 kg per ha calculated for 1975 is considerably higher than the figure of 2500 kg per ha given for the inland crop. The crop failure in 1974 was caused in the first place by poor germination (many beans rotted in the soil), after which the aphid attack was the finishing stroke. In 1969 all seedlings on plot I-A-3 were pulled up by birds. Germination and the seed-

Fig. 8. Subdivision of experimental field I during the years 1970-1972.

Fig. 9. Subdivision of experimental field II during the years 1970-1972.





ling stage are evidently critical phases for Celtic bean.

The excellent harvest of 1975 is somewhat surprising insofar as part of the crop was severely affected by aphids. The plants remained shorter in 1975 than in 1972 (when the yield was also good), but the number of pods per plant was very high. Also in 1975 the first root nodules were found to be present. It had therefore taken 6 years for the nitrogen-fixing bacterium *Azotobacter* to become established in the experimental field.

There is little to be said concerning any positive effect of manuring. In 1972 the state of the crop was somewhat better on the manured plot than on the unmanured one. The harvest too was slightly better. In 1975 however the harvest was no greater on the manured plot. Neither was there in 1975 any difference discernible between the two manured plots I-A-5 and I-A-7, of which the latter had first been effectively in use only since 1974 (in 1973 the crop had not come up).

6.5. *HORDEUM*

In the experimental period both *Hordeum distichum* and *Hordeum vulgare* were grown. The data are insufficient for a discussion of each species separately. Only in 1972 and 1975 were satisfying results obtained, although the yields were lower than those obtained at present for inland crops (4000 kg per ha). The exceptionally poor yield of 1969 was the result of plants dying (leaves turning yellow) after a reasonably good to good germination. In 1970 rather many young barley plants (Oderbrucker and Bigo varieties) had survived the salt-water flood. Despite the yellow leaves these plants continued to grow to some extent, but before long the crop steadily declined, so that no harvest was obtained. Some plants did actually come into ear, though at rather a late point in time (fig. 7d). In 1974, the plants which had escaped from being eaten by birds developed rather well, but feeding of animals on the ripe barley resulted in a totally failed harvest.

With barley some effect of manuring is usually discernible. Accordingly, in 1970 some time after the flood, the crop on the manured plot looked in better condition than that on the unmanured plot. In 1971, just before the crop was destroyed by cattle, the barley in I-A-4 was generally taller than in I-B-2. In 1972 the manured plot gave a considerably better yield than the unmanured one. In 1974 in mid-July the crop in I-A-2 (manured) looked in better condition than that in I-B-2, although the difference later became levelled out. Only in 1975 did the manuring have no effect, at least on the yield.

Somewhat contrary to expectation the results with barley were rather variable. In a brackish environment barley is clearly very sensitive to unfavourable factors. The results from the Westpolder would indicate that for the *terp* dwellers, barley was a less reliable crop than either gold-of-pleasure or flax.

6.6. *AVENA SATIVA*

The situation with oats in the Westpolder almost completely corresponds to that with barley. Both crops gave very little yield or none at all in 1969 and 1974. The peak year for oats and barley was 1972, while 1975 the yields for both were reasonable to good. The harvest in the good years was not different to the average yield for inland crops (4000 kg per ha). From the results of the Westpolder experiments one could possibly conclude that oats are certainly no less suitable for growing in a brackish environment than barley. In one year the oats clearly did worse than barley: in 1971 the oats had died off long before the crop was destroyed by young cattle, while the barley developed reasonably well.

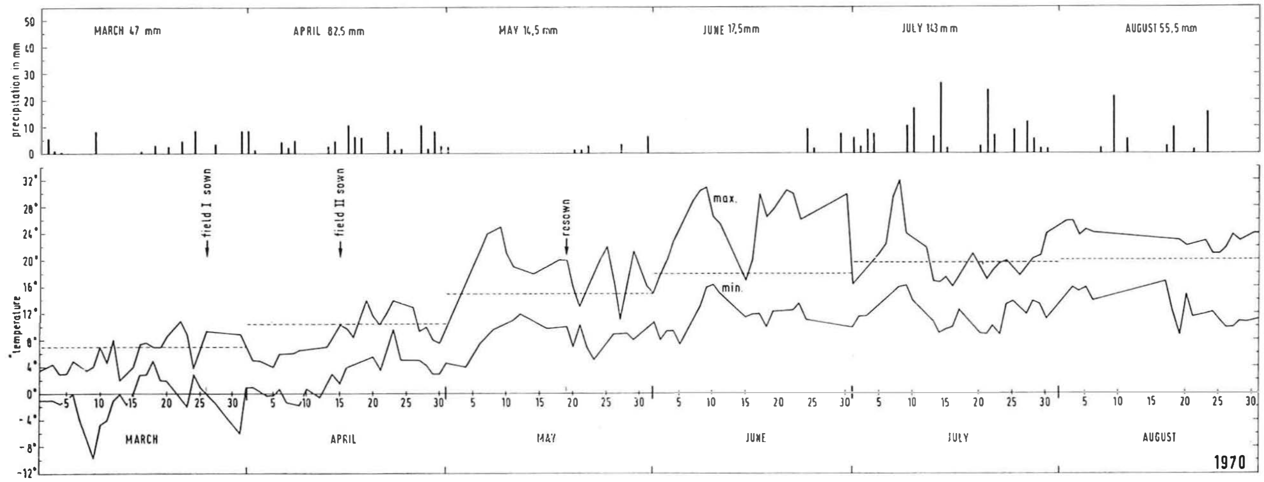
A possible effect of manuring is less clear with oats than with barley. In 1970, after the flood, the oats on the manured plot appeared to be in better condition than those on the unmanured plot. In 1972 the manured plot gave a markedly higher yield than the unmanured.

It is remarkable that of the two unmanured plots I-B-2 and I-B-6, both sown with oats in 1975, the latter, which had only recently been in use for the first time, gave a higher yield.

Fig. 10. Precipitation and temperatures from March 1st to August 31st 1970. See caption of fig. 4.

Fig. 11. Precipitation and temperatures from March 1st to August 31st 1971. See caption of fig. 4.

Fig. 12. Precipitation and temperatures from April 3rd to August 31st 1972. See caption of fig. 4.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APRIL 82,5 mm
MAY 14,5 mm
JUNE 17,5mm
JULY 143 mm
AUGUST 55,5 mm
precipitation in mm
temperature
field I sown
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max.
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MARCH
APRIL
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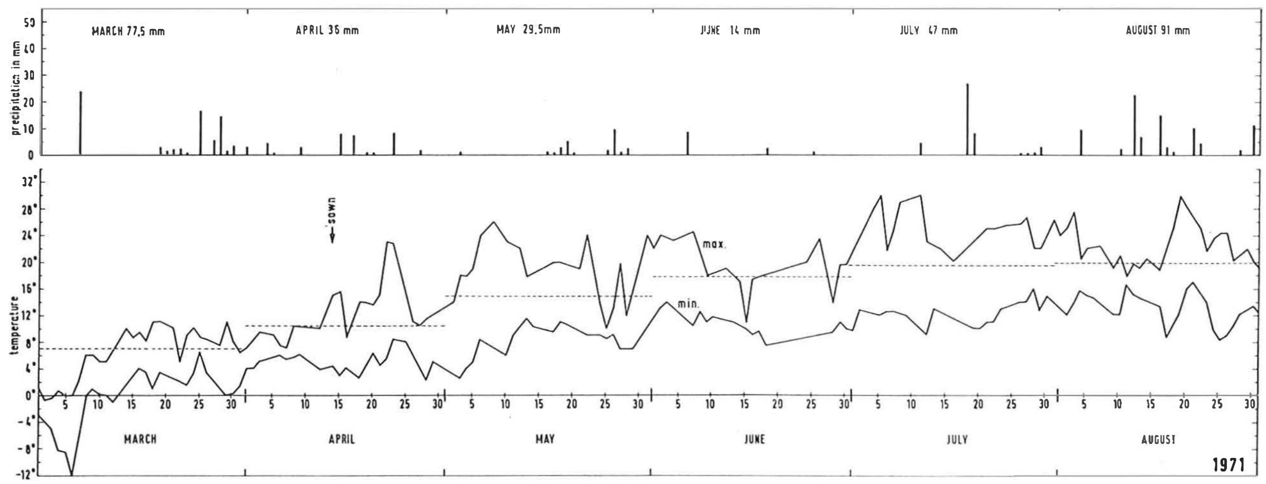
JULY
AUGUST
1970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MAY 29,5mm
JUNE 14 mm
JULY 47 mm
AUGUST 91 mm
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JULY
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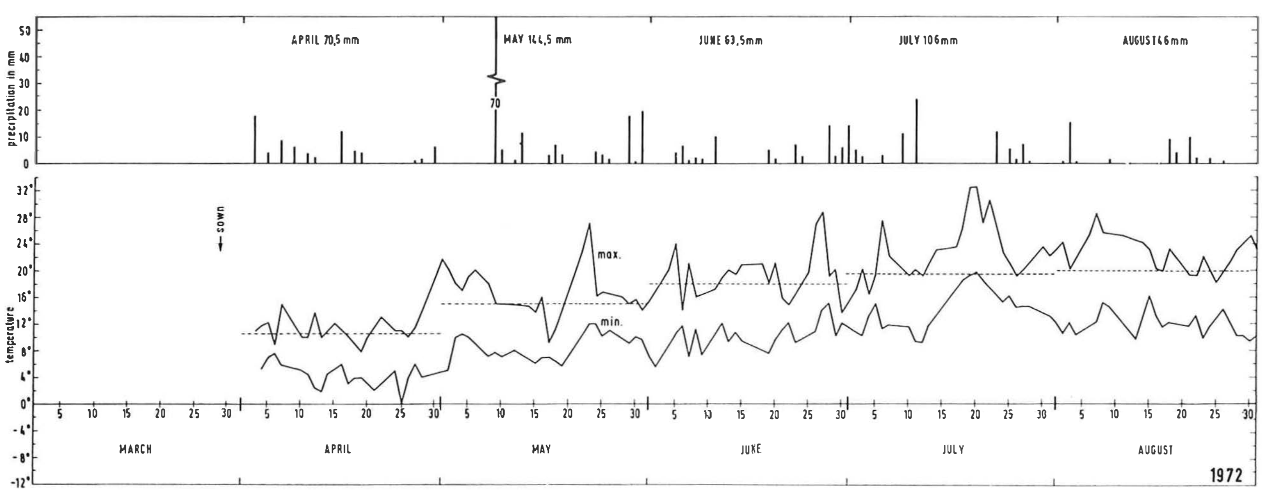
1971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JUNE 63,5mm
JULY 106mm
AUGUST 46mm
70
precipitation in mm
temperature
sown
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min.
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
1972

6.7. *OTHER CROPS*

From 1973 onwards, after field I had been enlarged, *Panicum miliaceum* (broomcorn millet) and *Triticum aestivum* (bread wheat) were included in the experiments. In 1973 there was no yield obtained whatsoever for any crop (5.5.1.). In 1974 only a few *Triticum aestivum* plants developed. In 1975 the results were somewhat better, although the estimated yield of 760 kg per ha is very low.

In 1974 the millet again did poorly, and no harvest was obtained. In 1975 this crop gave a modest yield despite poor development. It is clear that the experiments with millet and bread wheat should be continued for several more years, in order to ascertain how suitable these crops are for growing in brackish soil. The poor result for wheat and millet in 1975, when the other crops gave good yields, offers little hope however for better yields in the future.

Fig. 13. Field I on July 24th 1972. The crop plants are well developed.
Fig. 14. A few plants of *Vicia faba* var. *minor* amidst halophytic vegetation on field II (July 24th 1972).
Fig. 15. Sheaved barley (to the right) and oats (August 14th 1972).

6.8. *GROWTH CURVES*

During the – usually weekly – inspection of the experimental fields, measurements of crop height were included. It is obvious that the growth curve of a crop reflects the state of health of the species, indicating whether or not it is flourishing. Furthermore there appears to be a striking agreement between the degree of variation in the pattern of growth curves in different years and the fluctuations in yields. The growth curves for 4 crops are given in figs. 22-25.

It is mentioned above (6.2.) that gold-of-pleasure usually gives a reasonably good harvest and that the largest and smallest yields differ by a factor of about 2. As can be seen from fig. 22, the shape of the growth curves for *Camelina* in the different years is almost identical. For *Linum* too the growth curves for the different years are similar in shape (fig. 23), while the best harvest was about three times as great as the poorest yield. In contrast,

Avena gives a completely different picture: the growth curves for 1969 and 1974 run practically horizontal from the beginning of July onwards, while those for 1972 and 1975 are still rising steeply in July (fig. 24). A wide variation in yields (table 4) goes together here with important differences in the shape of the growth curves. A similar situation occurs with *Hordeum* (fig. 25): significant differences are apparent from both yields and growth curves. In this respect *Vicia faba* var. *minor* resembles barley and oats.

Summarizing, it can be seen that crops with a relatively even yield show little variation in the shape of the growth curves. For crops which gave yields varying from good to very poor, the shape of the growth curves can also vary considerably from year to year. For these species the development of the crop is clearly more dependent on external factors than is the case with flax and gold-of-pleasure.

7. THE NATURAL VEGETATION AND THE WEED FLORA

7.1. *THE VEGETATION OF THE HIGH SALT MARSH*

Within the fenced area of experimental field I, a strip of land 1.80 m wide was left uncultivated, in order to facilitate study of the natural vegetation on the highest part of the salt marsh. As a general rule the vegetation on the unprotected salt marsh is kept short by grazing, for which reason it is difficult to study. In 1975 the Westpolder salt marsh was no longer grazed after May, as a result of which the vegetation had developed well by July. This provided the opportunity to study the vegetation of the elevated outer margin of the salt marsh (the marsh bar) over a far greater area than inside the fence. Moreover, the salt marsh vegetation inside the fence was evidently influenced to a significant extent by activities on the experimental field.

As can be seen from table 5, the dominant species are *Festuca rubra* (red fescue) and *Agrostis stolonifera* (creeping bent). More or less typical halophytes occur in smaller numbers: *Aster tripolium* (sea aster), *Plantago maritima* (sea plantain), *Glaux maritima* (sea milkwort), *Puccinellia distans* (reflexed salt-marsh grass), *Spergularia marina* (lesser sea spurrey), *Spergularia media* (greater sea spurrey), *Trifolium fragiferum* (strawberry clover) and *Ameria maritima* (thrift). Despite the total absence of *Juncus gerardii* (mud rush), this vegetation belongs to the Juncetum gerardii. The very frequent occurrence of *Festuca* and *Agrostis* would indicate a rather dry environment (Beeftink 1965). This certainly applies to the high outer margin of the salt marsh, yet the vegetation on the lower-lying part of the salt marsh is similarly dominated by *Festuca* and *Agrostis*.

The rather abundant occurrence of *Trifolium repens* (white clover), just as the presence of *Potentilla anserina* (silverweed), would have been the result of grazing. Along the edge of the experimental field several "weeds" were present, such as *Polygonum aviculare* (knotgrass), *Atriplex* (orache) and *Cirsium vulgare* (spear thistle). Various "intruders" became established in the salt-marsh vegetation inside the fence, as a direct or indirect result of the agricultural experiment.

7.2. *THE WEEDS IN THE EXPERIMENTAL FIELD*

In table 6 are listed those plants which were found in different years in experimental field I in addition to the crops raised; these constitute the so-called weed flora. In the first year (1969) no weeding was done, in order to ascertain the composition of the weed flora on newly cultivated salt-marsh soil. In 1969, plants from the immediate surroundings, such as *Salicornia* (glasswort), *Spergularia* (spurrey) and *Glaux maritima* (sea milkwort) became established first in the cultivated plots. *Atriplex hastata* (spear-leaved orache), *Polygonum aviculare* (knotgrass) and *Senecio vulgaris* (groundsel) must have come from a somewhat greater distance from the experimental field. As long as the crops were standing in the field, these weeds played an unimportant role. Only after the harvest did several *Atriplex* and *Polygonum* plants develop into huge specimens (fig. 5).

In 1970 more than twice as many species of

Fig. 16. Young plants of *Hordeum vulgare* in field II (June 19th 1972).

Fig. 17. Fairly well developed barley in field II (July 24th 1972).

weed were encountered as in the previous year. The marked proliferation of halophytes in 1970 was probably a result of the flood at the end of April which practically ruined the crops, followed by the relatively warm and dry months of May and June. The weeds increased so rigorously that weeding had to be done, in order to keep down the weeds and to check excessive production of their seeds.

From 1971 onwards the plots were hoed and weeded regularly. In 1971 and 1973 no observations were made on the weed flora, because cattle broke into the experimental field and trampled everything, including the weeds. In 1972 no list of weeds present was made after the harvest, due to an oversight. In 1974 and 1975 there were a number of new species as compared with 1970, but on the other hand some species had disappeared. The relative proportion of halophytes sharply decreased in 1974 and 1975, though the number of non-halophytic weeds is far from constant. In 1975 there was still no question of a more or less stable weed vegetation. *Elytrigia pungens* (sea couch) developed into a weed which was difficult to eradicate, comparable with the inland species *Elytrigia repens* (couch).

8. COMPARISON WITH CAPPELERSIEL

As the only other agricultural experiment on unprotected salt marsh carried out previously is that of Körber-Grohne (1967, pp. 209-231), this will be briefly discussed here. This experiment was a sequel to the botanical investigation of the *terp* Feddersen Wierde, ca. 12 km north of Bremerhaven, at a short distance from the coast. The aim was to ascertain whether the crop plants, of which abundant remains had been found in the Feddersen Wierde, could in fact be grown on unprotected land in soil where conditions are brackish to some degree. In 1960, two small areas measuring 10 x 10 m^2 were dug up and fenced in on land used for pasture near Cappelersiel, ca. 13 km north of the Feddersen Wierde. The lower-lying enclosure I, from NN + 2.29 to 2.37 m (NN, Normal Null = NAP) was situated ca. 30 m away from a steep erosion cliff and ca. 300 m from the dike. Enclosure II, at a level of NN + 2.64 m, lay further in, about 150 m from the dike. Enclosure II was situated in approximately the same vegetation zone as field I near the Westpolder (ca. NAP + 2.10 m). The higher level of enclosure II at Cappelersiel with respect to mean sea level is attributable to the more extreme high tides in the Elbe-Weser region. There the NaCl concentration of the sea water is ca. 16‰, and in the Waddenzee 15-20 ‰.

Three crops were raised in 1960, namely *Avena sativa*, *Hordeum distichum* and *Vicia faba* (var. *minor*). Half of each enclosure was treated moderately with farmyard-manure. Development was favourable on the higher-situated enclosure II. The beneficial influence of manuring was remarkable in this respect. About 2 months after sowing, the barley on the unmanured area was 30-60 cm high, often with only 4 grains per ear; on the manured area the barley plants were 50-75 cm high, with an average of 18 grains per ear. Differences between crops grown on manured and unmanured soil were also shown by oats and beans. On the lowest-lying part of enclosure I, where barley had been sown, the young plants died off rapidly. *Avena sativa* and *Vicia faba* had developed reasonably well, and these crops did better on those areas which had been manured. Shortly afterwards enclosure I was flooded by three successive high tides, while enclosure II, situated at a higher level, was only once inundated. As a result of the flooding the crops on enclosure I died; on enclosure II the damage was less extreme. Although barley and oats mostly turned yellow, the grains developed well.

The yields in 1960 were not weighed, so that the difference in yield between manured and unmanured areas could not be ascertained. The crops on the manured areas had grown more vigorously and had formed bigger (and more) fruits than on the unmanured areas. The application of manure thus had a beneficial effect on crop growth, which was also manifested in the harvested product.

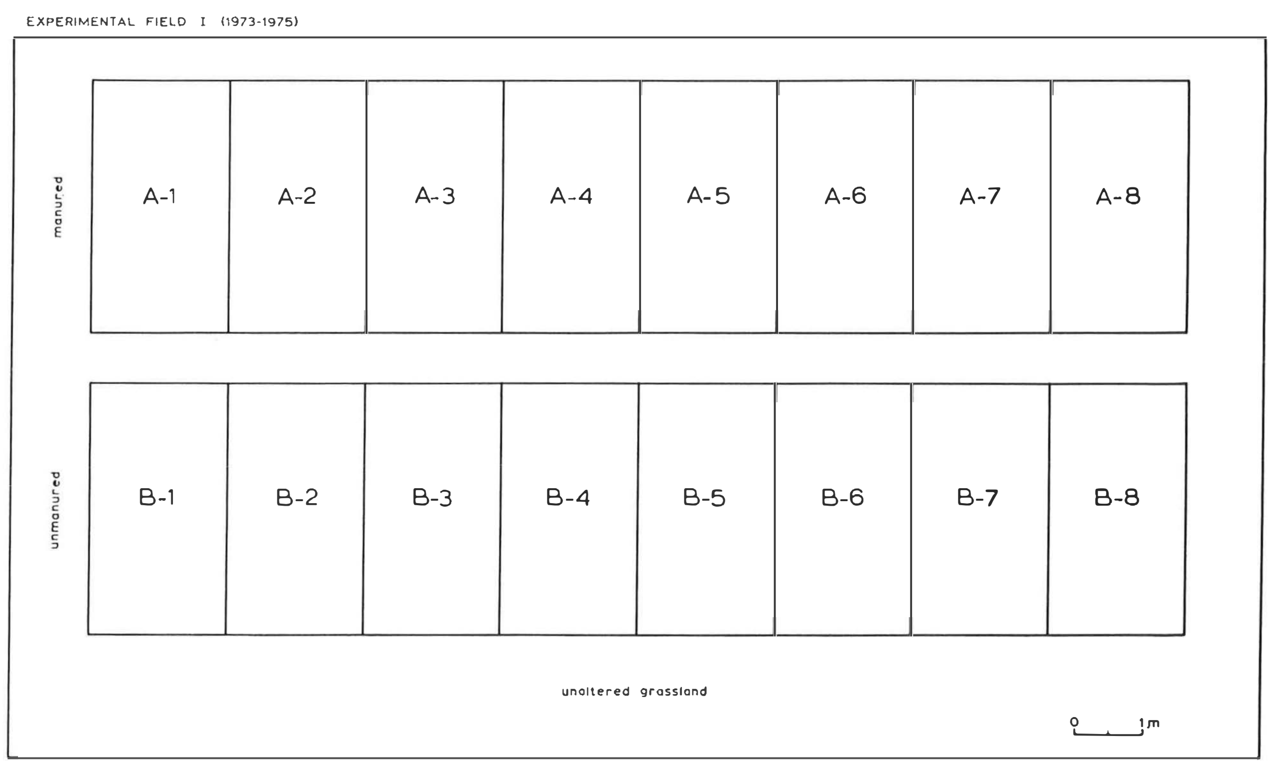
In the second year, 4 crops were raised: *Vicia faba* (var. *minor*), *Hordeum vulgare*, *Camelina sativa* and *Linum usitatissimum.* The enclosures of 10 x 10 m^2 were divided into 16 subareas of 2.5 x 2.5 m^2. On each enclosure four subareas were sown with each crop. All experimental plots were treated moderately with farmyard-manure. About 2½ weeks after sowing, at the germination stage, the low-lying enclosure I was flooded, and most plants did not survive. The few plants on enclosure I, which continued to grow, perished in a second storm surge in July, during which the enclosure was twice completely inundated. The crops on enclosure II developed well. During the storm surge in July, the enclosure was once or twice flooded completely or partly. As a result of this the leaves of the beans turned black, but the pods remained in good condition. On the barley the tips of the still green ears turned yellow; gold-of-pleasure showed no damage at all. The flax had suffered most from the flooding.

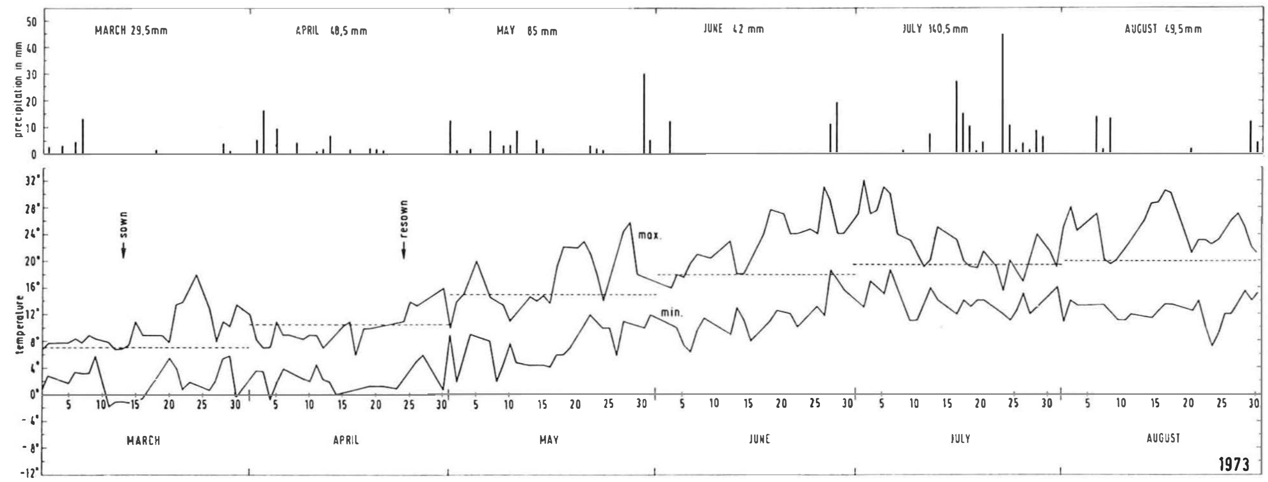
The influence of the storm surge of July was not equal over the whole of enclosure II; some areas were slightly damaged, others more so. This was also expressed in the yield, calculated in kg per hectare (table 7). Körber-Grohne concludes that *Camelina sativa* is the most resistant to salt and wind, followed by barley and then, some way behind, by *Vica faba*; the most sensitive of all is flax.

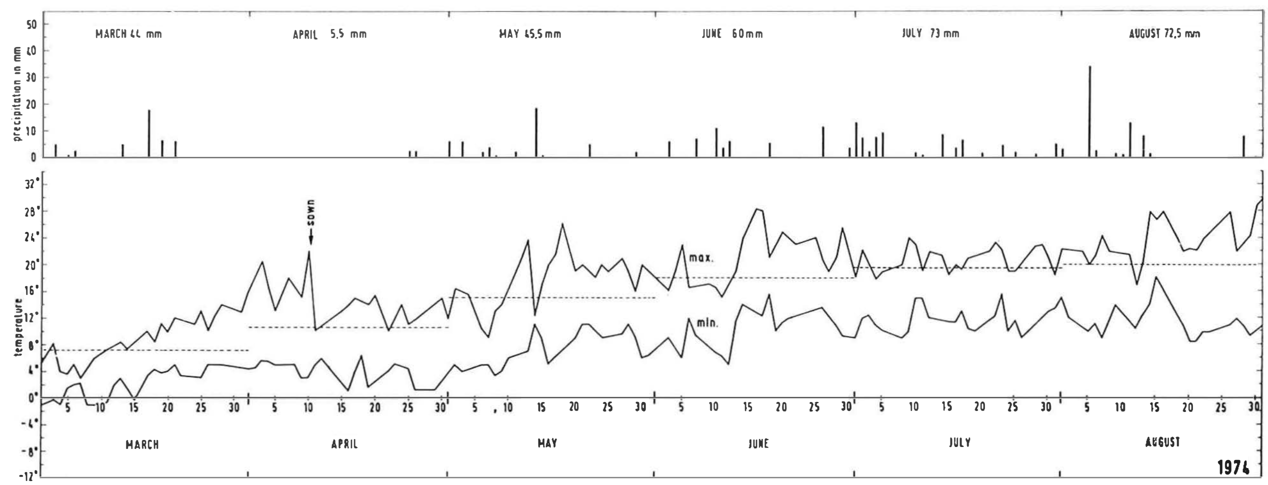
It is self-evident that a comparison should be made between the results from Cappelersiel and those from the Westpolder. Both experiments indicate that agriculture is only possible on the highest parts of the unprotected salt marsh. In both experiments, a flood during the germination stage resulted in almost complete destruction of the crops. The Westpolder results provide no information on the possible effects of flooding at a later stage of development.

In Cappelersiel, manuring clearly had a beneficial influence on the development and yield of beans, barley and oats. This was hardly ever the case in the Westpolder: sometimes the crop on manured plots looked better for a while than that on unmanured plots, but this difference often disappeared later. Only in 1972 was the yield of barley and oats on the manured areas significantly higher than on the unmanured areas. This was the peak year for both crops. It is feasible that manuring has an effect on the yield only under favourable conditions of crop development with abundant fruit-setting. Be this as it may, a far more marked effect of manuring on crop development is attested by the results of the experiment in Cappelersiel than is the case in the Westpolder.

Fig. 18. Subdivision of experimental field I during the years 1973-1975.




MARCH 29,5mm
APRIL 48,5 mm
MAY 85 mm
JUNE 42 mm
JULY 140,5mm
AUGUST 49,5mm
precipitation in mm
temperature
sown
resown
max.
min.
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
1973


MARCH 44 mm
APRIL 5,5 mm
MAY 45,5mm
JUNE 60mm
JULY 73 mm
AUGUST 72,5 mm
precipitation in mm
temperature
sown
max.
min.
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
1974

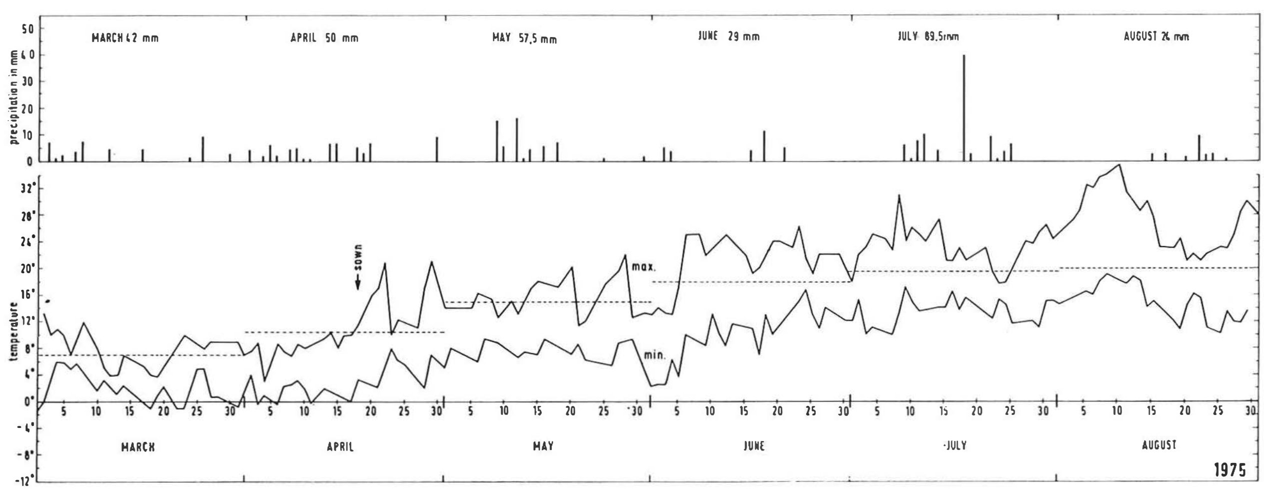

MARCH 42 mm
APRIL 50 mm
MAY 57,5 mm
JUNE 29 mm
JULY 89,5mm
AUGUST 24 mm
precipitation in mm
temperature
sown
max.
min.
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
1975

Fig. 19. Precipitation and temperatures from March 1st to August 31st 1973. See caption of fig. 4.
Fig. 20. Precipitation and temperatures from March 1st to August 31st 1974. See caption of fig. 4.
Fig. 21. Precipitation and temperatures from March 1st to August 31st 1975. See caption of fig. 4.

Körber-Grohne's conclusion that *Camelina sativa* is the most suitable crop for growing in a brackish environment is fully confirmed in the Westpolder. On the other hand, that flax is the most sensitive to salt and wind is contradicted by the results in the Westpolder. The results with barley in the Westpolder are far more variable than one would expect on the basis of the experiment at Cappelersiel. In evaluating the results from Cappelersiel it must be borne in mind that barley and beans were grown for two seasons and oats, flax and gold-of-pleasure for only one season.

The yields of barley and gold-of-pleasure in 1961 (table 7) fall within the range of yields obtained in the Westpolder. The flax yield in Cappelersiel is less than the worst harvest in the Westpolder.

9. SUMMARY AND CONCLUSIONS

Experimental field II on the unprotected salt marsh near the Westpolder, at a level of NAP + 1.55-1.60 m, gave very poor results, so that the experiment on this field was discontinued after 3 years. The crop failure of 1970 in field II was the result of a flood, which also largely destroyed the newly germinated crop in the higher-situated field I. The 1971 experiment was given up, because in both fields the crops were destroyed by young cattle in mid-July. In contrast to field I, where crop growth was reasonably good (except for oats), crop development in field II was poor. In 1972 field I gave a good harvest; in field II however results were poor: flax and Celtic bean gave no yield at all, with gold-of-pleasure and barley the yield was less than the input, and only oats gave a small positive net result. The failed harvest of 1972 was partly caused by the flood at the end of May, though even up until then development had been poor. The part of the salt marsh, where experimental field II was laid out, is evidently unsuitable for agriculture. The experiment on unprotected land near Cappelersiel also led to the conclusion that lower-lying parts of the high salt marsh are unsuitable for raising crops.

The results in experimental field I, on the other hand, show that agriculture is certainly possible on the unprotected salt marsh, provided that fields are laid out on the highest parts of the salt marsh, i.e on marsh bars and perhaps also on natural levees, where of course the chance of flooding during the growing season is least. Furthermore, on account of the sandy constitution of these higher parts, salts are rapidly washed out. More frequent flooding in the winter has no deleterious effect on crop growth, as is evident from table 4. Accordingly, in the winter of 1974/1975 experimental field I was certainly flooded 9 times, while the harvest of the following season was good to very good. The absence of exceptionally high tides during the growing season for the crops is essential for the success of agriculture on the unprotected salt marsh. The agricultural experiment in the Westpolder has shown that, provided cultivation was restricted to the highest parts of the salt marsh, the following crop plants could have been raised with a reasonable chance of success in the unprotected coastal region: *Camelina sativa*, *Linum usitatissimum*, *Vicia faba* var. *minor*, *Hordeum distichum*, *Hordeum vulgare* and *Avena sativa*.

In table 8 are summarized the results of 8 years of agriculture on the highest part of the salt marsh, i.e. experimental field I (including the experiment carried out by T. C. van Hoorn in 1968). Again it is evident from table 8 that in a period of 8 years twice the harvest failed completely as a result of a flood (1970, 1973) and twice a crop promising a reasonable to good yield was destroyed by cattle (1968, 1971). Twice the harvest was good (1972, 1975) and twice the harvest was a partial failure (1969, 1974). One can assume that the *terp* dwellers would have taken great pains to see that cattle could not destroy crops standing in the field. Accordingly, excavations have revealed fields surrounded by ditches. It is possible that measures were also taken to restrict feeding activities of birds, so that damage inflicted in this way was less severe than in the Westpolder. On the other hand, it would not have been possible to counteract unfavourable weather conditions (such as a long dry period with increasing salt concentration in the

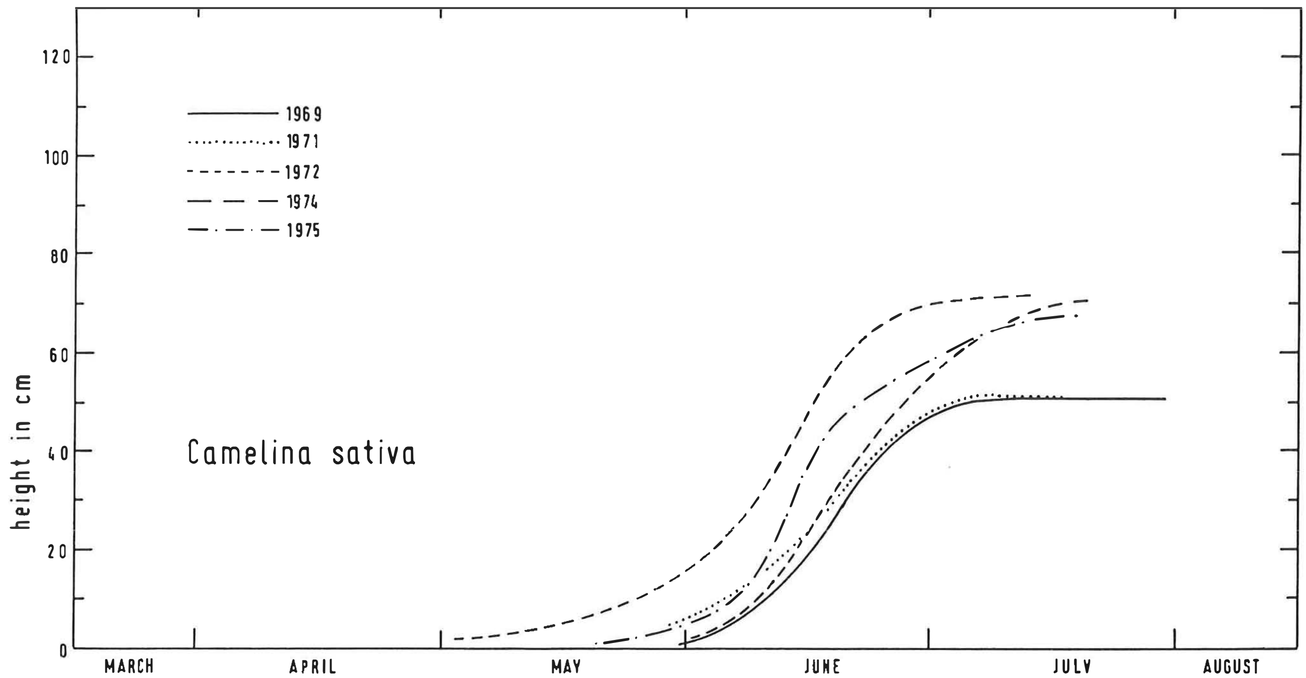


Fig. 22. Growth curves for *Camelina sativa,* field I, series B.

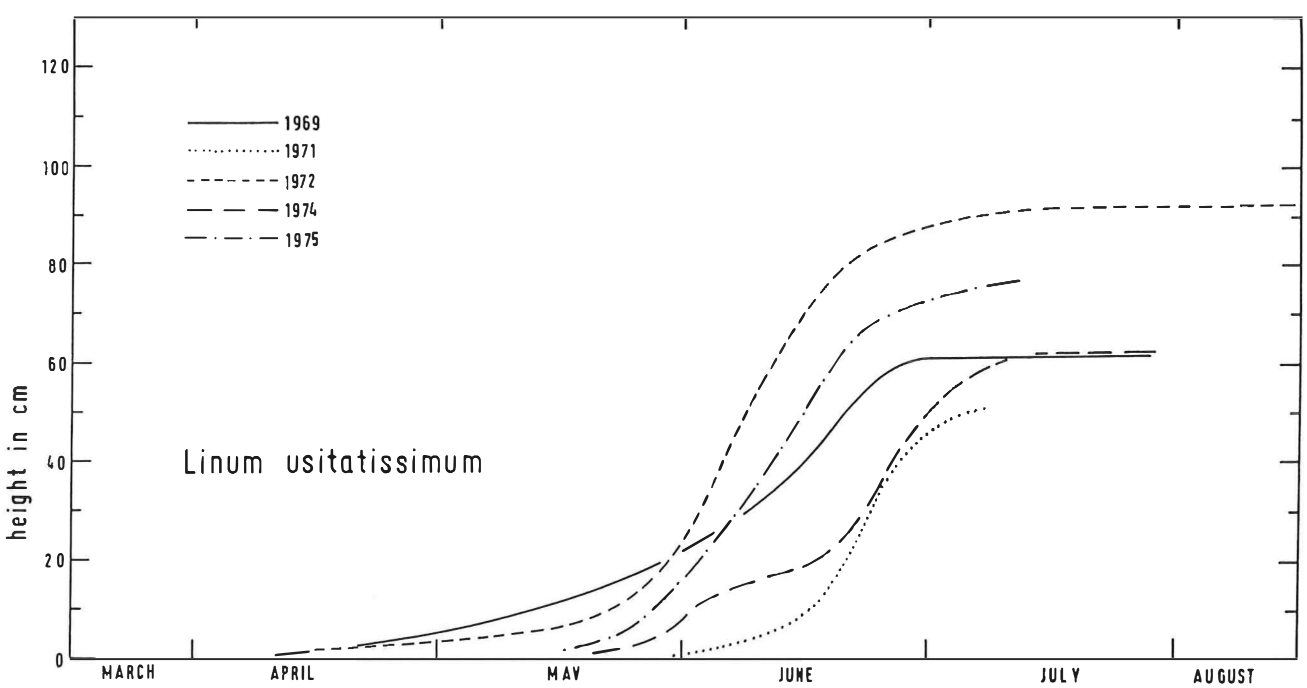


Fig. 23. Growth curves for *Linum usitatissimum,* field I, series A.

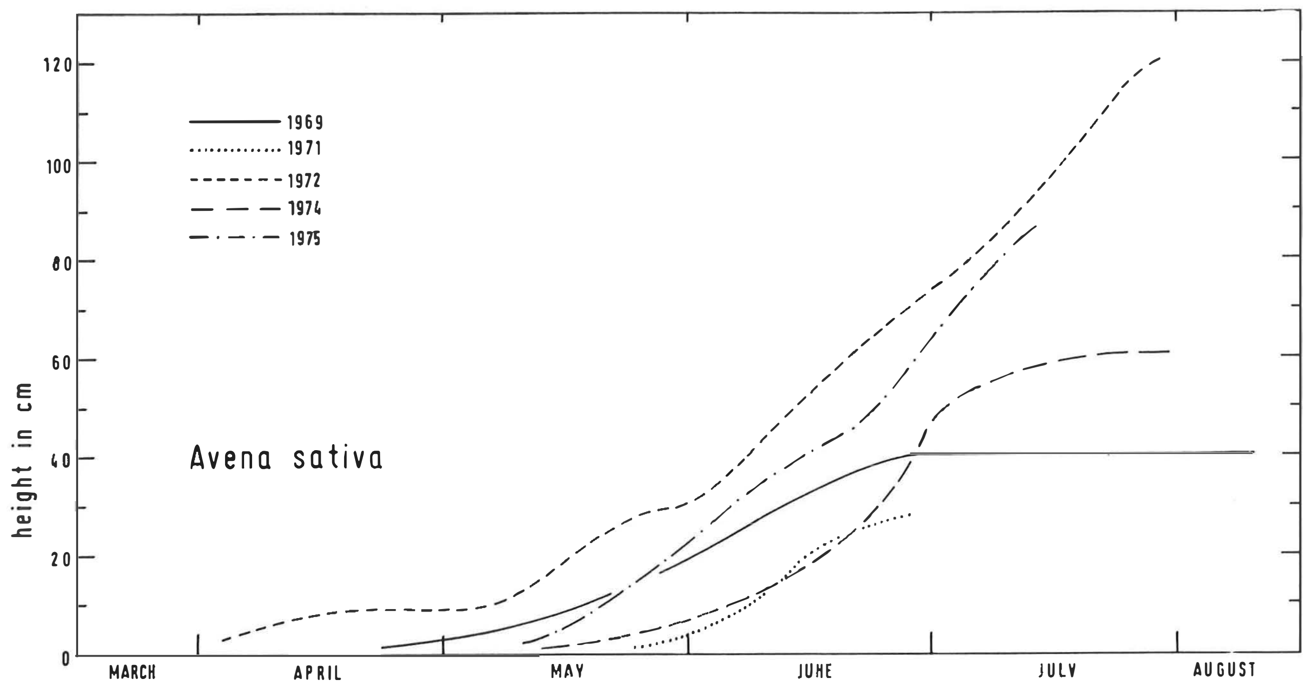


Fig. 24. Growth curves for *Avena sativa,* field I, series A.

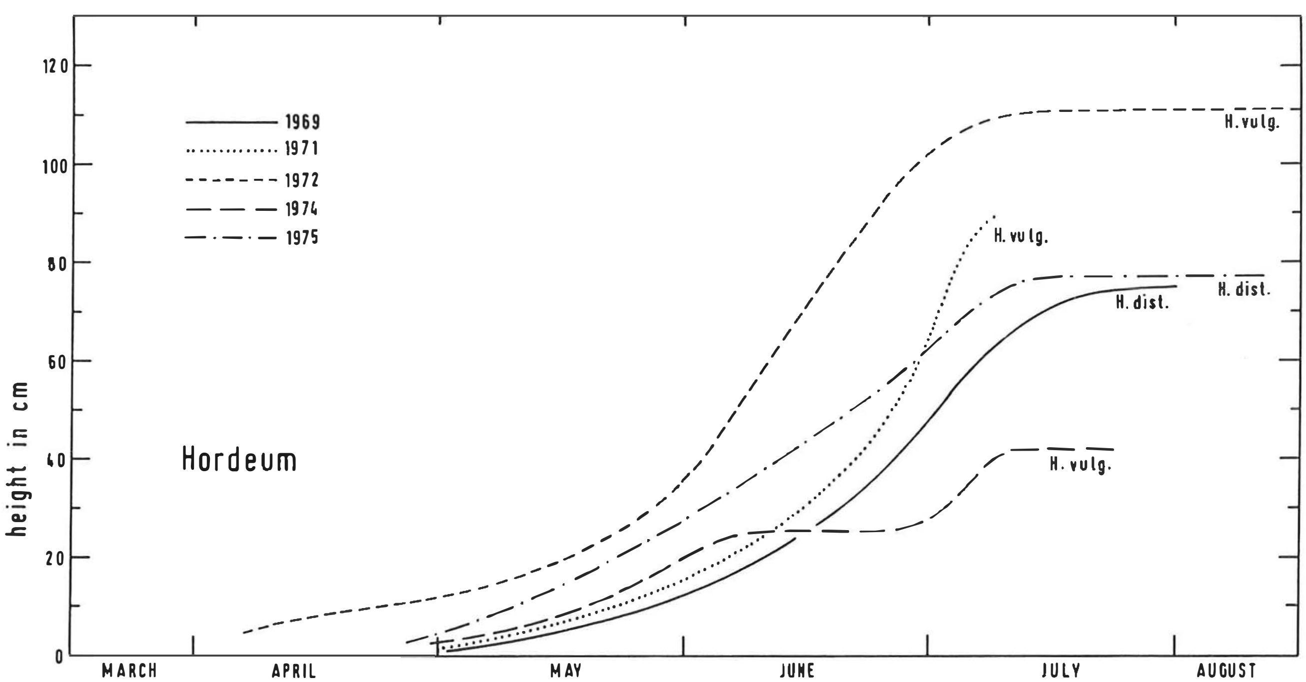


Fig. 25. Growth curves for *Hordeum* (*distichum* and *vulgare*), field I, series A.

soil), or aphids, thrips and other infections.

On the basis of two crop failures in 8 years due to the vehemence of the sea, it would be unjustifiable to conclude that the crops of the *terp* dwellers were also destroyed by salt water once every four years on average. An observation period of 8 years is too short for such conclusions to be drawn, and furthermore the frequency of storm surges in spring and summer could have been different formerly to now. In this connection the situation at Cappelersiel deserves further comment. Here, in both years of the experiment (1960 and 1961), the high-situated enclosure was flooded once in the summer. In the Elbe-Weser region, extremely high tides should occur regularly in July. Körber-Grohne (1967) speculates as to whether this was the case in prehistoric times also, for it is hardly conceivable that agriculture flourished in the surroundings of the Feddersen Wierde if the fields were flooded almost yearly in the summer.

It should be emphasized here that in former times agriculture in the unprotected coastal region was not restricted to the so-called regression phases, periods in which a lowering of sea level took place. A (relative) rise in sea level will be accompanied by the increase in height of the marsh-bar surface as a result of accumulation of silt to a level of ca. 1.20 m above mean high water. Marsh bars (and perhaps also natural levees) would therefore always have been suitable for agriculture to a certain degree. In periods of diminished storm-surge activity, the chance of a failed harvest as a result of flooding would have been less than during transgression phases, while the potential cultivation area was probably greater.

In assessing the risk run by the *terp* dwellers of a crop failure as a result of a salt-water flood, the following point should also be taken into consideration. The experimental areas of Cappelersiel and the Westpolder were laid out on a narrow strip of salt marsh outside the dike, such as that found in optimal extent in the present-day coastal area of the Netherlands and Northwest Germany. These narrow strips of salt marsh are exposed to the most extreme conditions possible with respect to high tides, partly as a result of the effect of the dikes in forcing the water level to rise. Before the constructions of the dikes, there extended along the coast an expanse of high salt marsh, usually several kilometres wide, with successive series of marsh bars. It took several hours for high tides to reach those parts of the salt marsh lying furthest inland. There may often have been insufficient time for storm surges which overflowed the outermost marsh bar, to inundate the highest parts of the salt marsh at 3 - 5 km from the coast. Agriculture on marsh bars and natural levees situated at a greater distance from the outer margin of the salt marsh would have involved a smaller risk of flooding. The risk of damage due to storms in the spring (flooding during the germination stage) could have been diminished by sowing relatively late.

It should also be borne in mind that crops raised by the *terp* dwellers possibly underwent natural selection as a result of which more salt-resistant varieties developed. This would have reduced the risk of poor results due to a temporary increase in salt concentration in the soil.

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Table 1. High tides recorded at Veerhaven-Oort (2 February 1969) and Lauwersoog

1969		1970				1971			
above 2.05		above 1.55		above 2.05		above 1.55		above 2.05	
date	water-level	date	water-level	date	water-level	date	water-level	date	water-level
2-2	2.45	3-2	1.63			1-2	1.60		
29-9	2.36		2.01			14-2	1.80		
1-10	2.09	7-2	1.57			10-3	2.46	10-3	2.46
9-11	2.07	9-2	1.62			16-7	1.63		
20-11	2.18	20-2	2.49	20-2	2.49	20-10	1.75		
29-11	2.70	27-3	1.77				1.95		
		28-3	2.29	28-3	2.29	21-10	1.60		
			1.74			22-10	2.07	22-10	2.07
		29-4	2.30	29-4	2.30	6-11	1.78		
		21-5	1.58			16-11	1.58		
		22-5	1.66			17-11	2.53	17-11	2.53
		15-7	1.58			21-11	2.72	22-11	2.72
		16-9	1.82			22-11	1.95		
		1-10	1.65			20-12	1.60		
		2-10	1.81			21-12	1.75		
			2.49	2-10	2.49				
		3-10	2.36	3-10	2.36				
			1.73						
		19-10	2.10	19-10	2.10				
		20-10	2.32	20-10	2.32				
			1.83						
		21-10	2.17	21-10	2.17				
		28-10	1.73						
		1-11	1.73						
			1.96						
		3-11	1.56						
		4-11	2.88	4-11	2.88				
		6-11	1.73						
		9-11	1.98						
			2.64	9-11	2.64				
		10-11	2.05						
		12-11	1.62						
		1-12	1.58						
		7-12	1.57						
		18-12	1.70						

in meters above NAP.

1972				1973		1974		1975	
above 1.55		above 2.05		above 2.05		above 2.05		above 2.05	
date	water-level	date	water-level	date	water-level	date	water-level	date	water-level
20-1	1.72			2-4	2.32	28-10	2.45	25-1	2.08
27-3	1.62			3-4	2.40	28-11	2.20	26-1	2.30
28-3	1.60			6-11	2.10		2.08		
16-4	1.72			13-11	3.10	4-12	2.52		
28-5	1.76				2.10	5-12	2.21		
21-10	1.58			16-11	3.03	12-12	2.45		
23-10	1.68			17-11	2.18	17-12	2.70		
24-10	2.08	24-10	2.08	19-11	3.30	18-12	2.18		
10-11	1.57			20-11	2.48	19-12	2.28		
11-11	1.95			25-11	2.28				
13-11	1.95				2.40				
21-11	1.60			6-12	3.00				
22-11	1.62			7-12	2.70				
29-11	1.60			13-12	2.06				
					3.42				
				14-12	2.21				
				15-12	2.53				
				17-12	2.07				
					2.40				

Table 2. Westpolder 1969. Determinations of moisture and salt content of soil samples (analysis Drs. J.N. Lanting).
The location of most of the samples is indicated in fig. 3.

number	date	description	water per 100 g of dry soil	mg Cl^-/ g dry soil	g Cl^-/ l water
1	March 31	east of plots 0-10 cm deep	24.3	0.63	2.60
2	March 31	west of plots 0-10 cm deep	20.0	0.89	4.43
3	March 31	from bottom of gully in low salt marsh	54.2	20.56	37.92
4	April 28	unploughed soil within fence, below sod	27.4	0.79	2.90
5	April 28	idem 10-20 cm deep	21.8	0.69	3.17
6	April 28	east of series A 0-10 cm deep	18.0	1.51	8.38
7	May 27	west of series B 1-5 cm deep	19.6	1.41	7.20
8	May 27	idem c. 20 cm deep	21.8	2.21	10.14
9	June 23	west of series A 1-5 cm deep	17.0	1.23	7.22
10	June 23	idem c. 20 cm deep	25.6	2.63	10.28
11	July 16	west of series A 1-5 cm deep	11.3	2.55	22.59
12	September 4	near ditch parallel to dike (NAP + 1.54 m), below sod	39.4	2.67	6.76

Table 3. Data on input and yield on the experimental fields in the undiked salt marsh near the Westpolder.

		1969				1970[1]		1971[2]			
		input in g	yield in g	yield/input	calculated yield in kg/ha	input in g	no plants (-) or few plants (±) left over	input in g	state before destruction by cattle	input	yield in g
FIELD I - series A	Linum usitatissimum	65	156	2.4	390	140	-	100	good	100	510
	Camelina sativa	10	336	33.6	840	25	±	20	good	19	740
	Vicia faba var. minor	80	-	-	-	200	±	180	mediocre	180	1790
	Hordeum distichum/vulgare	70	32	0.45	80	170	±	130	good	130	2640
	Avena sativa	65	30	0.46	75	130	±	100	poor	120	4000
	Camelina sativa										
	Hordeum distichum/vulgare										
	Vicia faba var. minor										
	Linum usitatissimum (blue-flowered)										
FIELD I - series B	Linum usitatissimum	40	444	11.1	1100	140	-	120	good	100	485
	Camelina sativa	5	155	31.0	390	30	-	25	good	22	868
	Vicia faba var. minor	60	391	6.5	980	200	±	180	good	180	1560
	Hordeum distichum/vulgare	50	62	1.2	160	170	-	140	mediocre	130	1525
	Avena sativa	50	53	1.1	130	160	-	120	poor	130	2950
	Triticum aestivum										
	Panicum miliaceum										
	Avena sativa										
FIELD II	Linum usitatissimum					90	-	90	-	90	-
	Camelina sativa					25	-	25	-	20	4
	Vicia faba var. minor					150	-	150	-	150	-
	Hordeum vulgare					130	-	130	-	130	79
	Avena sativa					120	-	120	-	135	259

1972		1973[3]	1974				1975				
yield/input	calculated yield in kg/ha	input in g	input in g	yield in g	yield/input	calculated yield in kg/ha	input in g	yield in g	yield/input	calculated yield in kg/ha	inland yield in kg/ha
5.1	690	100	60	435	7.2	590	60	890	14.5	1200	1000
38.9	1000	20	20	510	25.5	690	20	1150	57.5	1555	1200
9.9	2420	180	180	little	<1	-	180	2750	15.3	3715	2500
20.3	3565	130	130	4)	-	-	130	1150	8.8	1555	4000
33.3	5405	130	130	5)	-	-	130	2500	19.2	3375	4000
		25									
		130	130	4)	-	-	130	750	5.8	1015	
		180	180	little	<1	-	180	2760	15.3	3730	
							90	960	10.7	1295	
4.9	655	100	60	390	6.5	525	60	870	14.5	1175	
39.5	1175	20	20	640	32.0	865	20	1100	55.0	1485	
8.7	2110	180	180	little	<1	-	180	3000	16.6	4055	
11.7	2060	130	130	4)	-	-	130	1300	10.0	1755	
22.7	3985	130	130	5)	-	-	130	2850	21.9	3850	
		200	130	-	-	-	130	610	4.7	825	
		78	60	-	-	-	60	330	5.5	445	
		130	130	5)	-	-	130	3300	25.3	4460	
-	-										
0.2	10										
-	-										
0.6	200										
1.9	645										

1) Due to flooding in the seedling stage the crop failed.

2) Crop destroyed by young cattle.

3) Flooding in the seedling stage and devastation by cattle resulted in a total crop failure.

4) Due to damage inflicted by animals the barley which had developed fairly well gave no harvest.

5) The development of oats was poor; moreover the few ears were eaten barren.

Table 4. Extract of yield data from field I.
Yields from manured plots are indicated by an asterisk.

		1969		1972		1974		1975	
		input/ yield	calculated yield in kg/ha	input/ yield	calculated yield in kg/ha	input/ yield	calculated yield in kg/ha	input/ yield	calculated yield in kg/ha
Camelina	A	33.6	840	38.9	1000*	25.5	690*	57.5	1555*
	B	31.0	390	39.5	1175	32.0	865	55.0	1485
Linum	A	2.4	390	5.1	690*	7.2	590*	14.5	1200*
								10.7	1295*
	B	11.1	1100	4.9	655	6.5	525	14.5	1175
Vicia	A	-	-	9.9	2420*	<1	little*	15.3	3715*
						<1	little*	15.3	3730*
	B	6.5	980	8.7	2110	<1	little	16.6	4055
Hordeum	A	0.45	80	20.3	3565*	-	-	8.8	1555*
								5.8	1015*
	B	1.2	160	11.7	2060	-	-	10.0	1755
Avena	A	0.46	75	33.3	5405*	-	-	19.2	3375*
	B	1.1	132	22.7	3985	-	-	21.9	3850
								25.3	4460

Table 5. Vegetation on the high outer margin of the salt marsh (marsh bar) on which field I is laid out. Plant cover 100%. Survey on July 21st 1975.

4 very abundant; 3 abundant; 2 fairly abundant; 1 present; + rare

Festuca rubra ssp. rubra	4
Agrostis stolonifera	3
Aster tripolium	1
Trifolium repens	2
Odontitis verna	+
Lolium perenne	1
Plantago maritima	+
Elytrigia pungens	+
Glaux maritima	1
Potentilla anserina	+
Puccinellia distans	+
Spergularia marina	+
Spergularia media	+
Trifolium fragiferum	+
Armeria maritima	+

Along edge of experimental field:

Poa annua
Polygonum aviculare
Hordeum secalinum
Cirsium vulgare
Atriplex
Bromus mollis

Table 6. Weeds observed in experimental field I.

Year	1969	1970	1974	1975
Atriplex hastata/patula	+	+	+	+
Polygonum aviculare	+	+	+	+
Glaux maritima	+	+	+	+
Spergularia media/marina	+	+	+	+
Salicornia europaea	+	+	+	.
Agrostis stolonifera	+	+	.	+
Senecio vulgaris	+	+	+	+
Puccinellia distans	.	+	.	.
Suaeda maritima	.	+	+	+
Artemisia maritima	.	+	+	+
Aster tripolium	.	+	+	+
Stellaria media	.	+	+	.
Taraxacum officinale	.	+	.	.
Festuca rubra	.	+	.	.
Plantago maritima	.	.	+	.
Polygonum persicaria	.	.	+	.
Elytrigia pungens	.	.	+	+
Salsola kali	.	.	+	.
Urtica urens	.	.	+	+
Solanum nigrum	.	.	+	+
Coronopus squamatus	.	.	.	+
Sambucus nigra	.	.	.	+
Amaranthus	.	.	.	+

Table 7. Yield data for enclosure II at Cappelersiel in 1961 (after Körber-Grohne 1967, p. 230).

		calculated yield in kg/ha	yield/ input
Hordeum vulgare	slightly damaged	1175	10
	more seriously damaged	980	8
Camelina sativa	slightly damaged	1635	20
	more seriously damaged	1100	13
Linum usitatissimum	slightly damaged	310	3.9
	more seriously damaged	60	0.7

Table 8. Synopsis of results on field I.
++ good yield; + mediocre yield; - no yield;
between brackets the yield expectation.

year	valuation of yield	short description
1968	(++)	good crop development; destroyed by cattle
1969	+	partly reasonable yield
1970	-	flooding in seedling stage
1971	(+)	reasonable development (except oats); destroyed by cattle
1972	++	good yield
1973	-	flooding in seedling stage
1974	+	partial crop failure; no harvest of barley because of damage due to animals in the ripe crop
1975	++	good yield (except broomcorn millet and bread wheat)