Neth. J. agric. Sci. 26 (1978) 288-303

Ridge quality and potato growth

J. K. Kouwenhoven

Tillage Laboratory, Agricultural University, Diedenweg 20, Wageningen, the Netherlands

Accepted: 14 February 1978

Key words: Ridge size, ridge shape, soil tilth, soil temperature, soil moisture content, emergence, growth, yield, potatoes

Summary

Field and soil bin experiments carried out for 10 years indicate that potato growth can be considerably influenced by ridge quality, probably mainly by way of soil temperature, soil moisture content and soil covering on the tubers. Under Dutch conditions an optimum quality potato ridge contains about 600 cm^2 of loose soil in cross-section, has only a slightly flattened or a rounded top, has a fine tilth (mean weighed diameter $\leqslant$ 8 mm and no clods $>$ 40 mm) and is situated on a medium textured soil. Elsewhere, the optimum potato ridge, depending on climatic conditions, the occurrence of clods and stones and the predisposition for capping of the soil, can be deduced from the relationships discussed in this paper.

Introduction

Maximum saleable yield can be achieved by a high gross yield combined with a small amount of tubers which are green, blighted, wrong size or ill-shaped. Optimalization by ridge quality improvement of growing conditions of potato plants, such as soil temperature, soil moisture (transfer) and soil covering on the (seed) tubers, is a means of increasing saleable yield.

With regard to growing conditions (determined by emergence, crop development and yield) ridge quality can be characterized by ridge size, ridge shape and the tilth of the loose soil in the ridge, aspects that are mainly influenced by soil texture and tillage operations. Coarse gradings ($>$ 55 mm) are desired more and more by increasing demands made by the potato chip industries (van der Zaag, 1974). Moreover, the amount of small tubers ($<$ 35 mm) should be reduced to a minimum so as to minimize the growth of volunteer potatoes (Lumkes & Beukema, 1973). The influence of ridge size and planting depth on yield and grading has previously been studied by Hoekstra & van Wallenburg (1967) and Kouwenhoven (1967, 1970). They found a positive relationship between ridge size and saleable yield, due to coarser gradings and less refuse.

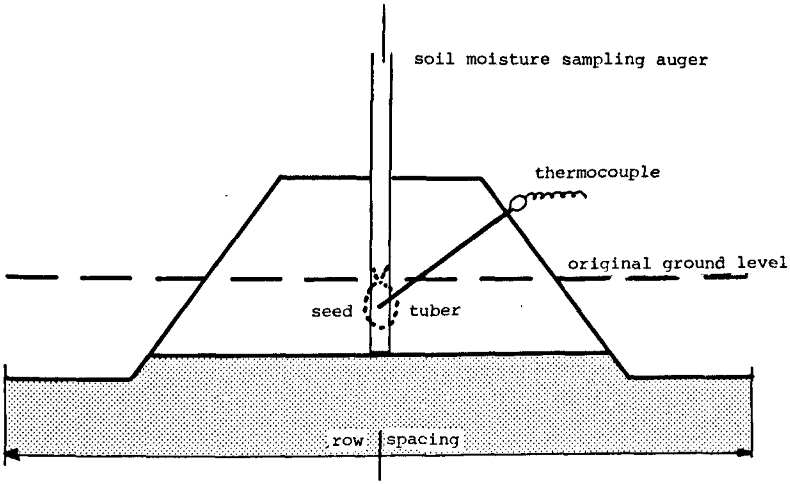

Fig. 1. Location of seed tubers, soil moisture sampling and temperature determination with thermocouples.

The relationship between ridge quality, growing conditions and harvesting results were studied in field experiments with relation to ridge size (1966) and with relation to row spacing, ridge size and ridge shape (1971-1974). In model experiments in soil bins it was mainly the relationship with ridge shape and tilth that was studied (1974-1976). In 1976 a glasshouse experiment was carried out on early growth (up to only 5 weeks after planting) with 3 objects and 2 replications and with a total of 216 seed tubers.

In all the experiments the plant population density was about 40 000 plants/ha and the planting depth was just below ground level with various shapes and sizes of the ridges (Fig. 1). The area of the experimental plots in the field varied from 0.01 ha (1966) to 1.00 ha (1971-1974) and the plots were laid out in quadruplicate according to the random block system. The area of the soil bin was 6 m × 12 m or 2 bins of 3 × 12 m. The number of replications was 2 per soil type (1974), 3 (1975) and 5 (1976); the number of plants in the soil bins was 240. Except for one of the bins in 1974, the potatoes were grown on 'stroomrug' soil with about 14 % clay. The grade of seed potatoes, cultivar Bintje, was 35/40 or 35/45 mm. Ridges were made at planting; weed control was carried out by pre-emergence application of Patoran.

Soil moisture content of the loose soil was measured in the middle of the ridge and temperatures at the level of the centre of the seed tubers (Fig. 1). At least 50 plants were harvested per replication and per object from field expriments and 10 plants from soil bin experiments.

The combined results of the experiments are discussed below.

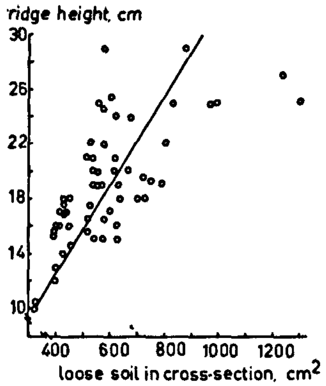

Fig. 2. The relationship between the area of loose soil in cross-section and the ridge height as ridge size indicators.

Ridge size

The size of a potato ridge is often characterized by its height, but especially with larger ridges, the relationship between ridge hieght and the amount of loose soil in cross-section of the ridge under field conditions is not very close (Fig. 2). Ridges with the same height may have different shapes and the non-loosened part at the bottom of the ridges (20 to 30 % of the ridge volume with row spacings of 67 cm and 105 cm, respectively) has not been considered. The amount of loose

Table 1. Ridge size, soil moisture content, soil temperature and emergence, growth and yield; field experiment 1966

Ridge size, loose soil in cross-section, cm²	270	460	580	Significance**
Soil on top of seed tuber, cm	4	6.5	8	
Moisture content, % w/w				
on 24/5	17.6	18.8	20.2	
on 8/6	12.9	14.4	16.9	
Temperature, daily mean at seed tuber level, mean of period from 16/5 to 25/7, °C	17.7	—	15.2	$P < 0.05$
Emergency, 50 %, days after planting	11	14	17	
Growth				
dry matter production, total g/plant on 23/6	68.0	67.6	82.4	
dry matter production, tubers only on 23/6	32.8	32.8	39.3	
dry matter production, total g/plant on 18/8	308.0	350.3	394.3	
dry matter production, tubers only on 18/8	246.6	284.5	315.9	$P < 0.10$
number of stems per plant	5.2	5.3	5.9	
Yield				
number of tubers per plant	22.4	22.3	21.8	n.s.
total tuber weight per plant, g	1233	1402	1542	$P < 0.10$
tuber weight*, g (rel.)	57.0(91)	62.7(100)	69.6(111)	
amount of green tubers, % w/w	20.7	15.0	5.5	

* Represents grading.

** If no significance level is indicated, the original observations are lacking. Soil 40 % clay; ridge shape sharp; planting date 4 May.

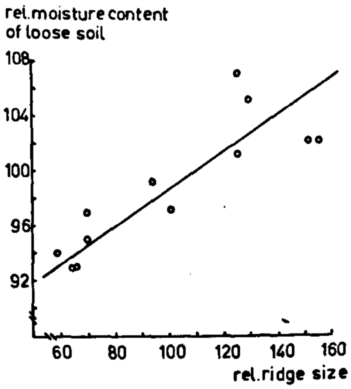

Fig. 3. Relative soil moisture content (100 = 20.7 % w/w) as influenced by the relative size of the ridge (100 = 580 cm^2).

soil in cross-section is therefore a better measure of ridge size than the height of the ridge.

Ridge size and soil moisture content

In the Netherlands potatoes often suffer temporarily from moisture shortage. Dry spells are especially disadvantageous during emergence and tuber formation. In field experiment moisture content of the loose soil in the ridges increased with an increasing ridge size (Table 1), also in very large ridges (Fig. 3). Large ridges formed not only a better buffer of available water, but also probably improved the transport of water from deeper layers, as could be deduced from the fact that moisture content was always higher in the large ridges. Within the ridges moisture content increased with depth (Fig. 4).

For these reasons, Hoekstra & van Wallenburg (1967) preferred ridges with a height of more than 16 cm, corresponding in Fig. 2 with a ridge size of about 500 cm^2. With an average ridge size of about 400 cm^2 in practice at that time (van der Zaag & Kouwenhoven, 1966), 500 cm^2 was indeed large.

Ridges of this size resulted in relatively high saleable yields and coarser grading than ridges of the current size. However, nowadays a size of 500 cm^2 of loose soil in cross-section is considered to be still below optimum.

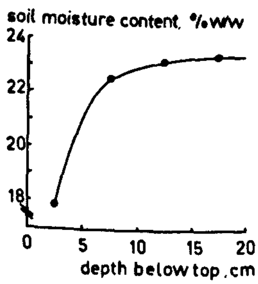

Fig. 4. Soil moisture content at different depths in a potato ridge (field experiment 1972).

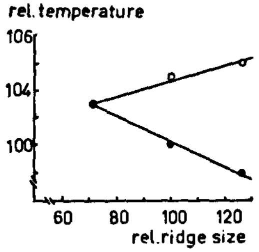

Fig. 5. Relative daily mean temperature at seed tuber level (100 = 15.2 °C) at shallow (o) planting, at the same depth from the top of the ridge and normal (•) planting, just below the original ground level, as influenced by the relative size of the ridge (100 = 550 cm²).

Ridge size and soil temperature

Generally, daily mean temperatures decrease from the top to the bottom of the ridge (Shaw & Buchele, 1957). With an increase in the ridge size, temperatures at the same depth from the top increase (Kouwenhoven, 1970), but they decrease at normal seed tuber level, just below the original ground level, as a consequence of the increase in soil covering (Table 1, Fig. 5). Temperature differences observed were more pronounced at the beginning of the growing season, before complete ground covering was obtained, than later on. Nevertheless, as ridging was carried out soon after planting, the lower temperature and also the higher moisture content near the tubers and the deeper soil covering, may influence emergence and further growth of the crop.

Ridge size and potato growth

Emergence. Under conditions where soil moisture content was sufficient for sprouting, increase of ridge size delayed emergence at a rate of about 1 day per 2 cm of soil covering and 1 day per ½ °C. The lower temperature at seed tuber level and particularly the longer distance for the sprouts to travel account for this delay (Table 1). Under dry and warm weather conditions and with a cloddy soil, however, deeper planting in larger ridges resulted in an earlier emergence (Kouwenhoven, 1970). Under wet and cold conditions, where temperature is the restricting factor, shallow planting in large ridges will result in the quickest emergence.

Growth. A delayed emergence did not simply mean a delayed crop growth during the whole growing season and, therefore, yield reduction. Dry matter production and the number of stems increased when the size of the ridge increased from 270 cm² to 580 cm² (Table 1). However, with ridge size increasing from 530 cm² to 735 cm², the opposite tendency was found (e.g. Table 2). Deep planting in very large ridges delayed crop growth over the whole growing season, in spite of the fact that crops on very large ridges seemed to suffer less from drought and stayed green for a longer time at the end of the growing season (Kouwenhoven & van Ouwerkerk, 1978).

Table 2. Row spacing, ridge size and general growth and yield characteristics; field experiments 1971-1974.

					R*	Significance
Row spacing, cm	67	75	90	105		
Average ridge size, loose soil in cross-section, cm²	530	575	680	735		
Growth (rel.)						
length of stems	80	100	104	101	75.4 cm	n.s.
number of stems/plant	107	100	93	92	6.0	n.s.
cluster width	98	100	110	110	27.9 cm	$P < 0.10$
occupation degree	103	100	91	88	79.8 %	$P < 0.05$
Yield (rel.)						
foliage	—	100	98	91	24.2 t/ha	$P < 0.01$
number of tubers per plant	121	100	95	91	18.1	$P < 0.05$
total tuber weight per plant	103	100	96	94	1166 g	$P < 0.05$
tuber weight	85	100	101	103	64.4 g	$P < 0.05$

*R = reference (= 100 %).

Yield. In connection with the growth effects mentioned, total tuber yield increased with an increase of ridge size up to 580 cm² (Table 1), but decreased with a further increase of the ridge size (Table 2). In both cases the number of tubers per plant decreased and the tuber weight increased, but to a lesser extent with increasing ridge size, so probably an optimum ridge size should be found between 500 cm² and 700 cm².

The relationship between ridge size (having a range within 250 cm² and 1050 cm²) and yield from many various experiments, compiled in Fig. 6, shows the optimum size to be about 600 cm². This size was also sufficient to reduce the number of green tubers to insignificancy (Fig. 7). Insufficient tilth, more stones, climatic conditions with high temperatures and moisture shortage are likely to shift the optimum in the direction of larger ridge sizes.

Ridge shape

The shape of the ridge should be adapted to the shape of the potato clusters, described as ellipsoids by Kouwenhoven (1970). Moreover, the shape sould be adapted to the climatic conditions. Under dry conditions a flat top and even a

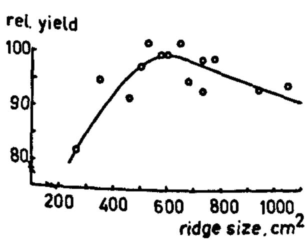

Fig. 6. The optimum ridge size, indicated by the maximum relative yield (100 = 51.1 tons/ha) in field experiments.

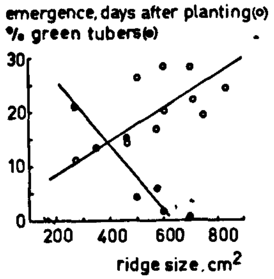

Fig. 7. Emergence of 50 % of the plants at the amount of green tubers, as influenced by ridge size in soil bin experiments.

furrow on the top of the ridge is preferred so as to catch as much water as possible; under wet conditions, ridges are given a sharp top in order to facilitate drainage.

Ridge shape and soil moisture content

Soil bin experiments on ridge shape and tilth in 1975 showed that the average soil moisture content, measured (Fig. 1) weekly over a period of 7 weeks (5 June – 22 July), was higher with flat ridges than with sharp ridges of the same size (Table 4). In 1976 sharp, flat-topped and flat ridges (Fig. 8A, B and C respectively) of the same size were made (Table 3). Moisture content was measured weekly in the middle of the ridges (Fig. 1) from the last ten days of May till the last ten days of August. Though the strongest differences were observed in June before complete ground covering was obtained, just as found in 1977, flat ridges had the highest moisture content, indicating that flattening of the top of the ridges may be beneficial under dry conditions.

Ridge shape and soil temperature

In 1976 temperatures at seed tuber level were measured in soil bin experiments by means of thermocouples from 14 April to 30 June (Fig. 1). The results are given in Fig. 8. In bare ridges, at the beginning of the growing season, the daily mean temperature at seed tuber level and the mean temperature fluctuation increased with increasing flatness of the ridges, but after completion of the ground covering by foliage, the opposite was found. The influence of ridge shape on the

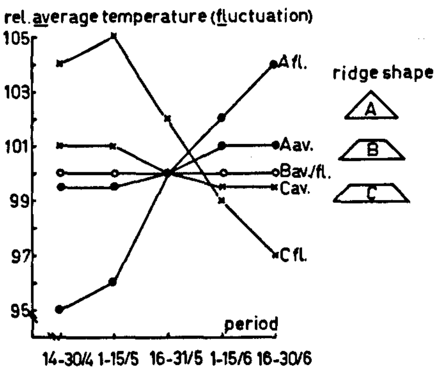

Fig. 8. The relative daily average temperatures (av) and average daily temperature fluctuations (fl), as influenced by ridge shape during different periods of the growing season.

Table 3. Ridge shape, soil moisture content, soil temperature and emergence, growth and yield; soil bin experiment 1976

				Significance
Ridge shape	sharp	flat top	flat	
Soil covering on seed tubers, cm	9.4	7.5	4.4	
Moisture content, % w/w, mean of period from 19/5 to 20/8	15.0	16.0	16.2	$P < 0.01$
Temperature, daily mean at seed tuber level, °C				
mean of period from 14/4 to 30/4	10.38	10.40	10.49	$P < 0.01$
from 16/6 to 30/6	21.23	21.01	20.89	$P < 0.01$
Emergence, 50 %, days after planting	28.0	26.0	25.5	
Growth				
length of stems, cm	77.6	76.2	76.6	n.s.
number of stems per plants	4.22	4.26	4.15	n.s.
cluster width, cm	31	32	34	$P < 0.10$
Yield				
number of tubers per plant	18	20	20	$P < 0.10$
total tuber weight per plant, g	1074	1198	1205	$P < 0.10$
tuber weight, g	59.7	59.0	60.3	n.s.
amount of green tubers, %	1.8	2.8	3.5	$P < 0.10$

Soil 14 % clay; ridge size about 550 cm^2 of loose soil; planting date 13 April.

daily mean temperature at seed tuber level in both periods, shown in Table 3, was rather small, nevertheless ridge shape clearly influenced potato growth.

Ridge shape and potato growth

Emergence. The higher temperature and moisture content at seed tuber level and the shorter distance for the sprouts to travel before they reach the surface, shortened emergence time as the shape of the ridges of the same size became flatter (Tables 3 and 4).

Growth. The influence of ridge shape on growth is also demonstrated in Tables 3 and 4. The length of the stems showed a slight (non significant) tendency to decrease, whereas the cluster width slightly increased in flatter, and thus wider, ridges of similar size. Similar results were found by Svensson (1962), by van Ouwerkerk et al. (1976) and by Kouwenhoven & van Ouwerkerk (1978). The increase in width and in other dimensions of the clusters was considerably smaller than the increase in width of the ridges with increasing row spacings, as demonstrated by the decrease in occupation degree* in Table 2. Regarding these

* Part of the cross-sectional area of the ridge, occupied by the cluster.

Table 4. Ridge shape, tilth, soil moisture content, soil temperature and emergence, growth and yield; soil bin experiment 1975.

	Shape	Tilth			Significance	
		fine	coarse	mean	shape	tilth
Soil covering on potato tubers, cm	sharp	12.0	12.5	12.2		
	flat	10.5	10.0	10.2		
	mean	11.2	11.2	11.2		
Moisture content, % w/w, mean of period from 3/6 to 22/7	sharp	17.0	16.0	16.5		
	flat	17.7	16.5	17.1	$P < 0.01$	$P < 0.01$
	mean	17.4	16.2	16.8		
Temperature, °C, daily mean at seed tuber level of period from 16/5 to 23/7		15.3	14.7	15.0	—	$P < 0.01$
Emergence, 50 %, days after planting	sharp	15	23	19		
	flat	13	17	15		
	mean	14	20	17		
Growth						
length of stems, cm	sharp	72.0	77.9	75.0		
	flat	67.5	78.8	73.1	n.s.	$P < 0.01$
	mean	69.7	78.4	74.0		
number of stems per plant	sharp	5.6	5.1	5.3		
	flat	5.1	4.6	4.8	$P < 0.01$	$P < 0.01$
	mean	5.3	4.8	5.1		
cluster width, cm	sharp	26.2	24.7	25.4		
	flat	27.4	26.5	27.0	$P < 0.01$	$P < 0.01$
	mean	26.8	25.6	26.2		
Yield						
number of tubers per plant	sharp	8.75	8.55	9.09		
	flat	9.70	9.35	9.53	$P < 0.01$	n.s.
	mean	9.23	8.95	9.09		
total tuber weight per plant, g	sharp	1190	1100	1150		
	flat	1160	1110	1130	n.s.	$P < 0.05$
	mean	1175	1105	1140		
tuber weight, g	sharp	136.5	128.8	132.7		
	flat	120.0	118.7	119.3	$P < 0.05$	n.s.
	mean	128.3	123.7	126.0		
underwater weight, g	sharp	384	381	383		
	flat	375	371	373	$P < 0.01$	n.s.
	mean	380	376	378		

Soil 14 % clay; ridge size about 700 cm² of loose soil; tilth 'fine' (MWD = 2.8 mm) and 'coarse' (MWD = 22.1); planting date 12 May.

figures, it should be kept in mind, that ridges made in row spacing experiments did not ondy become flatter, but also larger with increasing row spacings. As larger ridges are attended by relatively narrow clusters (Kouwenhoven, 1970), this could be one reason for the decreasing occupation degree found.

Yield. Svensson (1962) obtained considerably higher yields, under dry and cold conditions, with flat ridges, especially when they were made soon after planting, than with sharp ridges. In our experiments increasing flatness of the ridges was accompanied by an increasing number of tubers (Tables 3 and 4), the same (Table 4) or increased (Table 3) total tuber yield per plant, but also with a similar (Table 3) or decreased (Table 4) tuber weight, an increased amount of green tubers (Table 3) and a decreased underwater weight, indicating second-growth (Table 4). Therefore flattened or round-topped ridges may be less advantageous under Dutch conditions than has so far been assumed.

Soil tilth

Clod size distribution strongly influences the germination and growing conditions of potatoes. In particular, the fraction < 1 mm is attended by a relatively high moisture content (Kuipers, 1961) and increases the number of contact points suitable for soil moisture transfer (Boone & Franken, 1976). As an average of many fields and many years, in well cultivated potato ridges on medium textured soils in the Netherlands, about 85 % of the aggregates was found to be < 10 mm and even 25% < 1 mm. As the smallest fraction accounts for the majority of the contact points, this composition resulting in a mean weighed diameter (MWD) of 7.8 mm will in all probality be in the right range for sufficient moisture transfer.

Soil tilth and soil moisture content. The relationship between tilth and soil moisture was investigated by measuring soil moisture content in the middle of the ridges (Fig. 1), with a coarse (MWD = 22.1 mm) and with a fine (MWD = 2.8 mm) tilth for a period of 6 weeks (Table 4). Ridges with a coarse tilth were

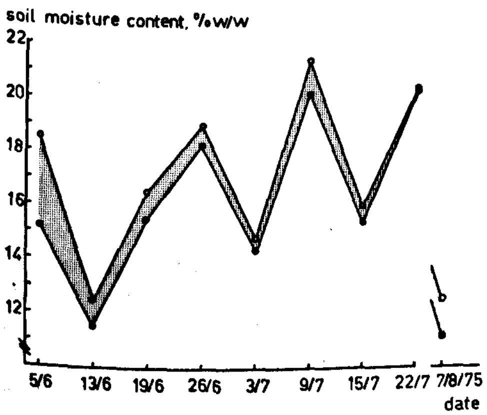

Fig. 9. Soil moisture content in the ridge as influenced by coarse (•) and fine (o) tilth on different dates during the growing season.

Table 5. Tilth, soil moisture content, soil temperature and emergence and primary growth; glasshouse experiment 1976.

	Soil	Tilth				Significance	
		fine	mixed	coarse	mean	moisture	tilth
Moisture content, % w/w,							
layer 0 - 15 cm,	wet	21.5	23.5	24.6	23.2		
mean of 5-week period	dry	15.6	17.5	17.9	17.0	P < 0.01	P < 0.05
	mean	18.5	20.5	21.3	20.1		
Temperature, °C, daily							
mean at seed tuber level,	wet	11.9	11.5	11.8	11.7		
mean of 5 weeks	dry	11.8	11.9	12.1	11.9	n.s.	n.s.
	mean	11.8	11.7	12.0	11.8		
Emergence, 50 %, days							
after planting	wet	17	22	25	21.3		
	dry	22	23	32	25.7		
	mean	19.5	22.5	28.5	23.5		
Growth, 5 weeks after							
planting	wet	20.5	18.5	16.6	18.5		
length of stems, cm	dry	14.2	13.2	9.1	12.2	P < 0.01	P < 0.01
	mean	17.3	15.8	12.8	15.4		
number of stems per plant	wet	2.5	2.5	2.7	2.6		
	dry	2.7	2.3	2.8	2.7	n.s.	n.s.
	mean	2.6	2.4	2.8	2.6		
diameter of stems, cm	wet	6.9	6.7	5.7	6.4		
	dry	6.7	5.7	4.4	5.6	P < 0.01	P < 0.01
	mean	6.8	6.2	5.0	6.0		
Total dry matter production, g	wet	81.1	65.1	35.1	60.4		
	dry	60.9	42.4	18.6	40.6	P < 0.01	P < 0.01
	mean	71.0	53.7	25.8	50.5		
Numbers of tubers per plant	wet	3.87	2.75	0.03	2.22		
	dry	3.72	2.5	0.00	2.08	n.s.	P < 0.01
	mean	3.80	2.64	0.02	2.15		

Soil 40 % clay; surface flat; planting depth 10 cm; tilth 'fine' (3 % > 10 mm); 'coarse' (95 % > 10 mm); 'mixed (50 % coarse + 50 % fine); moisture 25 % w/w at pF 2; planting date 13 February.

always drier than ridges with a fine tilth, though differences decreased in the course of the growing season, but increased again during a long period from about zero on 22 July to 1.4 % w/w on 7 August (Fig. 9). This effect was also notified by van der Zaag (1972). The fine tilth, being accompanied by a higher soil moisture content and probably caused by a better soil moisture transport, reduces the chance of moisture shortage during emergence and early growth.

The influence of tilth on emergence and growth was studied in a model experiment with 3 classes of tilth: coarse (MWD = 35.7 mm), medium (MWD = 20.3 mm) and fine (MWD = 4.6 mm) (Table 5).

Though attemps were made to keep soil moisture content a 2 levels, 'wet' and 'dry', equally for the three classes of tilths, soil moisture content increased with the coarseness (and at deeper levels) of the soil. Due to the fact that emergence and growth were still increasingly retarded with coarser tilths, it can be deduced that the transfer of moisture from the soil to the seed tubers was also severely hampered by the coarse tilth.

Soil tilth and soil temperature

The daily mean soil temperature at seed tuber level in a soil experiment, during the growth of the plants until complete soil covering was obtained, was lower with the coarser tilths (Table 4). This could be caused by a more pronounced evaporation on the coarser tilth. Differences between decreased during the growing season and disappeared after completion of the ground covering (Fig. 10).

Soil tilth and potato growth

Emergence. Emergence was delayed considerably by a coarse tilth (Tables 4 and 5). This could be explained from the lower moisture content and a poorer moisture transfer and from the relatively low temperature at seed tuber level (Table 4), but mechanical resistence to the sprouts and an inferior rootability will also play a role.

Growth. A coarse tilth delayed emergence and also the growth of the crop after emergence. In the model experiment in a glasshouse, the length of the stems, the diameter of the stems and the dry matter production, measured 5 weeks after planting, strongly decreased with increasing coarseness of the soil (Table 5). In the soil bin longer stems, but less stems per plant, were ultimately found with a coarse tilth (Table 4). Flowering was observed to be more abundant on a fine tilth than on a coarse tilth.

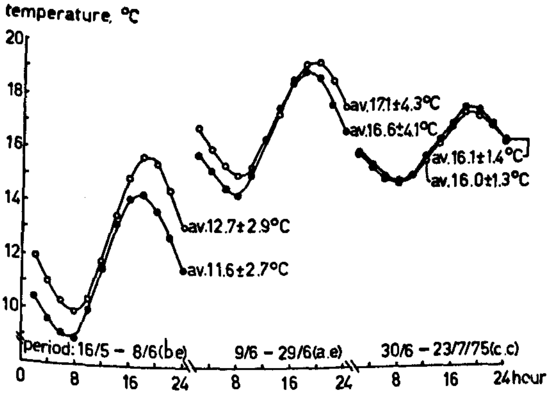

Fig. 10. Average daily course of soil temperature at seed level (11 cm soil covering) over 3 periods: before emergence (b.e.), after emergence (a.e.) and at completion of ground covering (c.c.) with coarse (•) and fine (o) tilth.

Table 6. Soil texture and emergence, growth and yield; soil bin experiment 1974.

	40 % clay	14 % clay	Significance
Emergence, 50 %, days after planting	28	24	
Growth			
length of stems, cm	46.6	60.7	$P < 0.05$
number of stems per plant	4.7	5.4	$P < 0.05$
cluster width, cm	25.6	29.3	$P < 0.05$
Yield			
harvesting date	29/9	30/8	
number of tubers per plant	11.6	20.8	$P < 0.01$
total tuber weight per plant, g	1143	1266	$P < 0.05$
tuber weight, g	99.7	60.9	$P < 0.01$

Planting date 18 April.

The fact that the plants on the coarse tilth suffered from drought can be attributed to the inferior moisture transport from clod to clod and from clod to root. Moreover, on the coarse tilth only the bottom layer was rooted, whereas on the fine tilth rooting occurred in all depths of the seedbed.

Yield. As could be expected from the growth observations, the number of tubers was highest on the fine tilth, 5 weeks after planting (Table 5) and the number and tuber weight at harvest (Table 4). Moreover, the total tuber yield per plant was higher and the underwater weight seemed to be higher on the fine tilth. The lower yield (Table 4) on coarse tilths was probably due to retarded emergence and growth (Table 5). The (non-significant) lower underwater weight (Table 4) indicates that second growth could occur more frequently with coarse tilths. The results are strongly in accordance with the findings of Hoekstra & van Wallenburg (1967), Kouwenhoven (1970) and Marinus & Bodlaender (1975).

Soil texture

For favourable growing conditions for potatoes requiring a rather fine tilth, the clay content of the soil should preferably not exceed 25 % (de Smet, 1975). Though power take-off driven implements have improved seedbed preparation, sufficient crumbling of the soil is often still a problem. Therefore, ridges are relatively small and cloddy on heavier soils. Clods made at or after seedbed preparation remain on the whole intact until harvest. For example, on the very easily crumbling soil in the soil bin (1975) with 14 % clay, only 25 % of the total amount of clods > 10 mm had crumbled in the period between planting and harvesting, without any further cultivation.

Relatively small and cloddy ridges on heavy soils are connected with relatively low moisture contents and with a low moisture conductivity of the soil (Hoekstra

& van Wallenburg, 1967, van Loon, 1975; Borst, 1977). On light and unstable soils, on the other hand, a very fine tilth can promote capping and at harvest new clods can be formed when small, wet aggregates stick together.

Results from soil bins situated next to each other, containing a medium-textured and heavy soil, are shown in Table 6. On the heavy soil emergence, growth and harvest date were delayed and the yield, consisting of a relatively small number of large tubers, was lower than on the light soil.

Discussion

Very large ridges (e.g. 800 to 1000 cm^2) can only be made with row spacings $>$ 75 cm. As in row spacing experiments (Table 2), the number of plants per ha was maintained with all row spacings, besides size and shape of the ridge, tuber growth at a later stage was also affected by competition between the relatively narrow-spaced plants (Svensson, 1973), but early growth is more likely to depend on ridge size than on plant spacing. The decreasing number of tubers with an increase in ridge size found with relatively small ridges (Kouwenhoven, 1970) was still observed (Table 2). The larger and wider ridges with wider row spacings were accompanied by a delay in growth and the crop showed a better resistance to dry periods, indicating a better moisture transport from deeper layers. With smaller ridge sizes, flat ridges were accompanied as well by more green and blighted tubers than sharp ridges of the same size, whereas with very large ridges with wider row spacings, the amount of green tubers was negligible.

From the increase in tuber weight with wider row spacings (Table 2) it can be deduced that the ridge size also had more influence than plant spacing on potato growth. The fact that wider row spacings were accompanied by lower yields, could be partly caused by the deteriorating plant arrangement.

Shadbolt et al. (1961) state that the temperature in the ridge is related with the angle of incidence of the sun, and they suggest that wind has perhaps a greater influence than the sun. They found a net cooling effect produced by the presence of furrows. This could be an explanation for the relatively high temperature and moisture content found in flat ridges, as they are accompanied by relatively small and shallow furrows.

In the field, coarser tilths were attended by lower soil moisture contents. The fact that in the model experiment (Table 5) the coarse seedbed was the wettest unlike conditions in the field and the emergence was even later than on the seedbed with the fine tilth, strengthens the importance of the moisture transfer from the soil to the seed tuber and the roots, favoured by a fine tilth. Though soil moisture in particular strongly influenced potato growth, it became clear that not only soil moisture and temperature regulate emergence, growth and yield of potatoes; rootability, mechanical resistance and perhaps other factors also play a role, expecially under different climatic conditions. Emergence was probably stronger influenced by the soil covering on the seed tuber than by the relatively small differences in temperature at seed tuber level.

Since soil moisture content increased with increasing size and flatness of the ridges, under dry conditions large and flat ridges will be advantageous.

Conclusions

Ridge quality, characterized by size and shape and by the tilth and texture of the soil and largely depending on climatic and soil conditions, strongly influenced potato growth.

Increase in *ridge size* was attended by a lower daily mean temperature and a higher moisture content of the soil at seed tuber level and a delayed emergence under cold and wet weather conditions. Below the optimum ridge size of 600 cm^2, increase in ridge size was accompanied by a higher yield and coarser grading; above optimum ridge size, increase in ridge size was accompanied by a decrease in dry matter production, a lower yield, coarser grading and the absence of green tubers.

Increase in *ridge flatness* was accompanied by a higher daily mean temperature at seed tuber level with a bare soil and with a lower temperature after completion of ground covering, with a higher moisture content, an accelerated emergence and further by a decreasing number and length of the stems, an increase in the percentage of green tubers and an increase in yield and probably a finer grading.

Increase in *fineness of tilth* was accompanied by a higher temperature and a higher soil moisture content at seed tuber level, with an earlier emergence and better growth resulting in a higher dry matter production and yield with a coarser grading and probably less second growth.

Increase of *clay content* of the soil was accompanied by delayed emergence and plant growth, a lower number of shorter stems, a lower yield and a coarser grading.

In the Netherlands a ridge with a cross-section of 600 cm^2 of loose soil, an only slightly flattened or rounded top and angles of the sides to the horizontal of 40° to 45°, with a rather fine tilth on a medium textured soil, meets local requirements the best.

Acknowledgments

The author wishes to thank H. Hooghoudt, H. A. C. Suy and E. Luitjens for their efforts on the subjects as students and R. Terpstra and P. Looijen Jr. for their cooperation in dealing with the long drawn out technical aspects of the work.

References

Boone, F. R. & A. A. Franken, 1976. Kieming en opkomst van het tweede gewas in de akkerbouwdubbelteelt van groentegewassen. *Landbouwk. Tijdschr.* 88: 270-274.

Borst, N. P., 1977. De betekenis van water in de grond en voor de plant. *Bedrijfsontwikkeling* 8: 161-163.

Hoekstra, C. & C. van Wallenburg, 1967. Bodemgesteldheid en teelt van consumptie-aardappelen op de Zuidhollandse eilanden. *Kali (Amst.)* 72: 61-68.

Kouwenhoven, J. K., 1967. Recent development in potato ridging on marine soils in the Netherlands. *Eur. Potato J.* 10: 257-271.

Kouwenhoven, J. K., 1970. Yield, grading and distribution of potatoes in ridges in relation to planting depth and ridge size. *Potato Res.* 13: 59-77.

Kouwenhoven, J. K. & C. van Ouwerkerk, 1978. Optimum row spacing for potatoes. *Potato Res.* 21 (in press).

Kuipers, H., 1961. Water content at pF 2 as a characteristic in soil cultivation research in the Netherlands. *Neth. J. agric. Sci.* 9: 27-35.

Loon, C. D. van, 1975. De teelt van aardappelen op zware grond. *Bedrijfsontwikkeling* 6: 832-836.

Lumkes, L. M. & H. P. Beukema, 1973. The effect of cultivation procedure on the liability of groundkeepers. *Potato Res.* 16: 57-60.

Marinus, J. & K. B. A. Bodlaender, 1975. Response of some potato varieties to temperature. *Potato Res.* 18: 189-204.

Ouwerkerk, C. van, K. Kooy, J. K. Kouwenhoven & C. D. van Loon, 1976. Grotere rijenafstanden bij aardappelen. Rapport No 25, PAGV Lelystad.

Shadbolt, C. A., O. D. McCoy & T. M. Little, 1961. Soil temperature as influenced by bed direction. *Proc. Am. Soc. hort. Sci.* 79: 488-495.

Shaw, R. H. & W. Buchele, 1957. The effect of the shape of the soil surface profile on soil temperature and moisture. *Iowa St. Coll. J. Sci.* 32: 95-104.

Smet, L. A. H. de, 1975. Geschiktheid van grond voor de teelt van aardappelen. *Bedrijfsontwikkeling 6:* 825-831.

Svensson, B., 1962. Some factors affecting stolon and tuber formation in the potato plant. *Eur. Potato J.* 5: 28-39.

Svensson, B., 1973. Development of potato stands in relation to their density. *Swed. J. agric. Res.* 3: 3-12.

Zaag, D. E. van der, 1972. Invloed van teeltmaatregelen op de kwaliteit van aardappelen. *Bedrijfsontwikkeling* 3: 51-61.

Zaag, D. E. van der, 1974. Productie- en teelttechnische ontwikkeling bij consumptie en pootgoedteelt. *Bedrijfsontwikkeling* 5: 995-999.

Zaag, D. E. van der & J. K. Kouwenhoven, 1966. Ruggen-opbouw bij aardappelen op klei- en zavelgronden. *Kali (Amst.)* 68: 255-261.