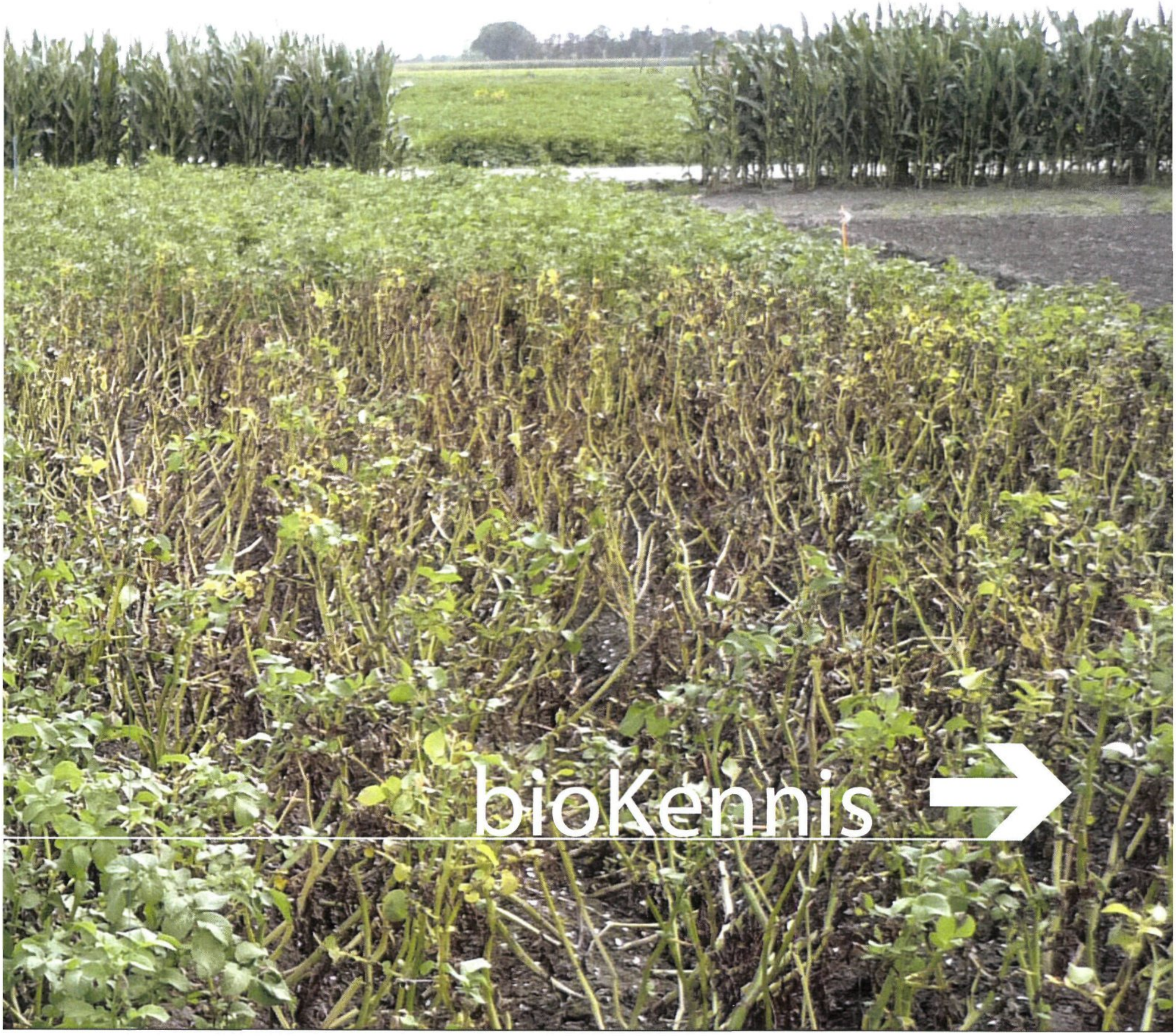
Low rate copper products to control Phytophthora infestans in potatoes in 2009



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Low rate copper products to control *Phytophthora infestans* in potatoes in 2009

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1 Introduction

Potato late blight, caused by *Phytophthora infestans,* causes substantial losses in organic potato production in the Netherlands. In the last years and especially in 2007, late blight was an enormous problem. The disease led to very low tuber yields. Also the tuber quality was poor. The risk of low and unpredictable yields is too high. That is why organic farmers planned to reduce the acreage with organic potatoes.
On the other hand the Dutch government stimulates organic cropping, including potatoes. Their ambition is an annual growth of 5% in acreage of organic agriculture. To support this, a research program was started in which research into measures to reduce the negative effects of late blight was an important topic.
Resistant varieties against late blight could be the solution. Breeders are rather successful in this. There are three interesting new varieties, Sarpo Mira, Bionica and Toluca with a high resistance against *Phytophthora infestans* but they also have some less respected characteristics, so it still is no breakthrough. Growers still have to use rather susceptible varieties.
In common agriculture growers successfully use fungicides to protect their potato crop against late blight and also in some neighbouring countries some fungicides are allowed in organic potato growing.
At the moment – 2009 - in the Netherlands, copper products are, according to the Dutch pesticide law, not allowed at all to use to protect potatoes against late blight.
Between Dutch organic growers the late blight problems lead to discussions in which a temporary registration of copper products is also suggested. Some growers do not want any pesticides at all, while others see that biological potatoes from abroad are sold in the super markets in years when Dutch organic potatoes are scarce. Those potatoes come from countries, where copper products are allowed. They speak about competition falsification.
In the research program to stimulate organic production the choice is made also to investigate the efficacy of copper and other products that are allowed in neighbouring countries in organic farming.
In the experiment of 2008 different copper containing products were tested. In 2009 this was repeated with the same products, but also other doses and combinations.

2 Materials and methods

2.1 Trial set up

The potatoes were grown on a sandy clay soil at the Applied Plant Research - PPO-AGV - location at Lelystad. The experiment was treated conform local good agricultural practice. Trial figures are listed in table 1. The trial design is presented in Appendix 1.

Table 1. **Trial figures**

	Lelystad
Soil	Light clay (14 % lutum)
Organic matter	2.4%
CaCO3	5.8%
Cultivar	Agria
Leaf blight resistance	5.5 – fairly susceptible
Tuber blight resistance	8 – fairly good resistance
Row distance	75 cm
Distance in the row	33 cm
Planting date and technique	6 May mechanically
Nitrogen fertilization; quantity and date	170 kg N per ha (11 May)
Plot size net	45 m x 11 m
Number of treatments	6
Number of replicates	4

2.2 Spraying

Potato plants were sprayed for the first time on 29 June when they had reached a height of 45 cm and the crop was almost closed.
Fungicide applications were carried out using a trial site sprayer with Airmix 110.04 nozzles. Nozzles were hanging approximately 50 cm above the foliage. Sprayings were carried out based on 300 l/ha. With the trial site sprayer up to ten treatments can be sprayed in one run; see figure 1.
The frequency of sprayings was decided by the DSS Dacom Advice module to ensure that timing was as good as possible. The sprayings were carried out on 29 June, 3, 6, 13, 17 and 24 July and on 4 August (In total 7 times).
To prevent the development of weeds, before crop emergence, on 15 May, the soil was treated with 0,25 l Centium + 1 l Butisan + 0,5 l oil in 400 l of water per hectare.
On 13 August haulm killing was carried out with 4 l Reglone per hectare.

2.3 Treatments

In the trial different copper containing products and two combinations of products were tested. They are listed in table 2. K1; A fungicide in a dosage of 600 gram Cu/ha, as cuprous oxide Cu_2O, was used as a standard; the other products are also under code. There was no difference in the timing of the different treatments.

Table 2: **Treatments**

Factor code	Factor description
K0	untreated
K1	600 g/Cu/ha/spray
K2	400 g/Cu/ha/spray
K3	100 g/Cu/ha/spray
K4	100 g Cu/ha/spray + 4x full dose of product X[1]
K5	100 g Cu/ha/spray + in June/July half dose product X and in August full dose product X

[1]) Product X was added on 3, 6, 13 and 17 July

2.4 DSS and weather conditions

Sprays were timed according to the Decision Support System (DSS) Dacom Advice module. See for more information about DSS Dacom Advice module the world wide web for DSS and Dacom.
Timing of applications was based on previous spray, variety, crop growth, weather conditions, weather forecast, blight in the crop itself and blight pressure in the neighbourhood.
In an experiment at a distance of 10 – 200 m, to increase the infection chances, artificial inoculation was carried out on 19 June. Subsequently artificial irrigation was carried out to prolong the leaf wetness period and from 24 June a fast spread of late blight was observed in that artificially irrigated experiment.
Weather conditions during the growing season are presented in Appendix 2. April was a dry month with a total precipitation of 18 mm. May, June and July were warm and sunny.The precipitation in May was normal (85 mm), June was rather dry (67 mm) and July, after the 5th was wet for three weeks (total in July 142 mm). After that, a rather dry period followed for more than a month in Lelystad.

2.5 Disease observations and artificial inoculation

To determine the effects of the different products and product combinations late blight observations were carried out weekly, and if necessary twice a week. Every time the percentage by *Phytophthora infestans* destroyed foliage (leaves and stems) was estimated visually.
Artificial inoculation was not carried out. On 3 July the first infections became visible, close to another late blight experiment that was artificially inoculated and was regularly and often sprinkler irrigated to stimulate late blight development.

2.6 Statistical analyses

Analysis of variance was made using GENSTAT 12.1. The control treatment K0 was excluded. The LSD; the least significant difference at p (probability) = 0.05 means that differences between the blight scores higher than the mentioned value in the column are significantly different.

Figure 1: One of the beams of the Sosef-trial-spraying machine (in another experiment).
Every time the spraying machine goes to the experimental field 10 different products can be sprayed.

Figure 2: 17 July. On the right plot 1, K0; untreated; on the left plot 3, K1

Figure 3: 3 August; infection of *P. infestans* in the experiment

Figure 4: 3 August; overview experiment. In front left plot 1 and right plot 2.

3 Results

3.1 Crop development

23 June: 70% soil coverage and a plant height of 35 cm.
3 July: 100% soil coverage and a plant height of 55 cm. The crop flowers.
20 July: 95% soil coverage and a plant height of 70 cm. The crop still flowers and remains rather up right.
3 August: 90% soil coverage and a plant height of 75 cm. Flowering is almost over and the crop is starting to lodge.

3.2 Disease development

The assessments of late blight in the foliage on 9 dates, are presented in Appendix 3 and the averages per treatment, including the results of the statistical analysis, in table 3.
From the 6th of July the infection pressure was high.

Table 3. **Foliage infestation per date (0% = completely free from late blight; 100% = completely destroyed by blight)**

treatment	3/07	6/07	10/07	16/07	20/07	27/07	3/08	10/08	13/08
K0	0.028	0.06	0.10	35.0	46.3	60.0	93	98	99
K1	0.003	0.02	0.08	5.3	8.3	8.5	31	40	51
K2	0.005	0.02	0.09	5.3	9.0	8.8	36	45	56
K3	0.002	0.03	0.04	3.8	7.0	9.0	49	68	81
K4	0.004	0.03	0.03	1.8	2.5	3.3	36	44	51
K5	0.002	0.01	0.01	4.0	6.0	7.0	35	45	58
Fprob*1	0.68	0.88	0.053	0.097	0.33	0.43	0.003	<0.001	<0.001
LSD (0.05)*1	0.006	0.05	0.006	2.8	6.9	7.3	7.4	9.6	11.6

*1 The control treatment K0 excluded

- The amount of late blight increased much faster in the control treatment K0 than in the other treatments in which copper was used. Significant differences between the treatments K1 – K5 occurred from 3 August onwards (F-probability <0.05).
- When we accept 35% dead foliage as a limit for haulm killing, than with all treatments except treatment K3, haulm killing could be postponed with 18 days by spraying with these copper containing products compared to the untreated.
- K2. Comparing K1 and K2 differences were limited and not significant. There was a tendency for a little bit more late blight in the 400 g copper treatment K2.
- K3. The 100 g copper treatment, at first was comparable with treatments K1 and K2. From 3 August onwards treatment K1 en K2 gave a significant better protection compared to treatment K3.
- K4. The 100 g copper treatment to which at 4 sprayings, starting when late blight pressure was high, per spraying a full dose of product X was added, resulted in August in a comparable protection compared with treatment K1, but in July treatment K4 seemed to give a somewhat better protection.
- K5. K5 resulted till August in a comparable protection compared to K3. In August protection was significantly better and comparable with K4. With K5, it was planned to apply 100 g Cu/spray. By

mistake only 50 g Cu was applied in spray 2 to 5. Therefore in total in treatment K5 500 g Cu was given and 4 doses of product X, see table 4.

Table 4. **Amount of copper (Cu) and number of doses of product X per hectare**

treatment	39/06	3/07	6/07	13/07	17/07	24/07	4/08	total
K1	600	600	600	600	600	600	600	4200
K2	400	400	400	400	400	400	400	2800
K3	100	100	100	100	100	100	100	700
K4	100	100+1d	100+1d	100+1d	100+1d	100	100	700+4d
K5	100+½d	50+½d	50+½d	50+½d	50+½d	100+½d	100+1d	500+4d

Figure 5: 3 August. On the right plot 1, K0; untreated; on the left plot 3, K1

4 Conclusions

- All five treatments significantly slowed down infection with *Phytophthora infestans.*
- When 35% dead foliage is accepted as a limit for haulm killing, than with all treatments except treatment K3, haulm killing could be postponed with 18 days by spraying with these copper containing products. With K3 this difference in haulm killing date was some days less; about 14 days.
- Comparing K1 (600 g Cu/ha/spraying) and K2 (400 Cu/ha/spraying) differences were limited and not significant.
- Also with K4 and K5 late blight control was comparable (not significantly different) with K1; the control copper treatment.
- Only treatment K3 (100 g Cu/ha/spraying), from August onwards, resulted in a somewhat lower late blight control as compared to the other treatments.
- Still remarkable was the effect of only 100 g copper, in a compound different from cuprous oxide, per spraying compared to the untreated control (K0). With only 100 g copper per spraying the crop was infected much slower compared to no protection at all.

Appendix 1. Trial design

Treatments

Factor code	Factor description
K0	untreated
K1	600 g/Cu/ha/spray
K2	400 g/Cu/ha/spray
K3	100 g/Cu/ha/spray
K4	100 g Cu/ha/spray + 4x full dose of product X
K5	100 g Cu/ha/spray + in June/July half dose product X and in August full dose product X

6 treatments; K0, K1, K2, K3, K4, K5
4 replications; R1, R2, R3, R4
Variety; Agria
Plot size 11 m * 4.5 m
Total trial size 22 m long * 72 m wide

24 R4 K1	22 R4 K4	20 R4 K2	18 R3 K5
23 R4 K0	21 R4 K3	19 R4 K5	17 R3 K4

16 R3 K3	14 R3 K0	12 R2 K4	10 R2 K1
15 R3 K2	13 R3 K1	11 R2 K5	9 R2 K2

8 R2 K0	6 R1 K2	4 R1 K3	2 R1 K5
7 R2 K3	5 R1 K4	3 R1 K1	1 R1 K0

Appendix 2. Weather conditions

. Weather data Lelystad May-June 2009

date	T-gem (°C)	T-max (°C)	T-min (°C)	rainfall (mm)	RH-min (%)
16-05-09	11.7	15.7	7.1	0	64
17-05-09	11.8	14.9	9.8	20.8	69
18-05-09	12.9	16.5	9.0	0	50
19-05-09	13.4	18.4	7.8	0	52
20-05-09	13.2	17.6	7.5	0	50
21-05-09	13.7	17.6	9.8	0	50
22-05-09	12.6	16.5	7.5	0.6	50
23-05-09	16.0	20.0	11.0	0	47
24-05-09	14.5	18.4	10.2	0	49
25-05-09	15.9	22.7	8.2	0	47
26-05-09	14.5	18.0	10.6	25	70
27-05-09	12	14.1	9.4	1.2	60
28-05-09	14.1	16.5	10.6	0.2	66
29-05-09	14.3	20.2	7.1	0	34
30-05-09	15.9	21.4	9.9	0	39
31-05-09	18.1	23.9	11.9	0	43
01-06-09	18.7	24.5	13.7	0	42
02-06-09	15.6	19.5	12.0	0	50
03-06-09	12.5	14.1	11.0	0	50
04-06-09	10.6	12.5	8.9	1.8	58
05-06-09	10.7	13.5	8.1	0.6	52
06-06-09	11.9	16.0	5.9	0	44
07-06-09	12.0	15.5	9.5	12.8	58
08-06-09	12.9	17.5	7.5	0.2	54
09-06-09	14.6	18.8	11.6	5.2	61
10-06-09	13.8	16.6	11.8	11.4	61
11-06-09	12.8	15.3	11.6	16.2	67
12-06-09	13.4	15.9	10.7	0	56
13-06-09	14.0	20.9	5.5	0	45
14-06-09	16.2	19.8	11.6	0	64
15-06-09	15.4	18.4	13.2	0	61
16-06-09	14.2	17.8	10.3	0.4	61
17-06-09	15.6	21.6	7.3	0	49
18-06-09	16.9	19.1	14.9	0.2	50
19-06-09	15.0	16.6	13.3	0	58
20-06-09	14.5	16.6	12.7	4.8	60
21-06-09	13.3	16.1	11.0	5.4	62
22-06-09	13.5	16.8	9.4	0	67
23-06-09	15.2	21.0	8.5	0	51
24-06-09	16.9	22.3	11.0	0	54
25-06-09	19.4	25.5	13.2	0	50
26-06-09	19	24.5	14.2	1	64
27-06-09	19.4	23.2	16.8	7.4	69
28-06-09	20.4	24.5	17.1	0	62
29-06-09	19.9	24.5	14.4	0	65
30-06-09	19.2	22.6	15.4	0	73

Weather data Lelystad July -August 2009

date	T-gem (°C)	T-max (°C)	T-min (°C)	rainfall (mm)	RH-min (%)
01-07-09	19.7	25.6	14.4	0	63
02-07-09	21.8	28.5	14.3	0	53
03-07-09	21.4	30.2	17.0	1.6	48
04-07-09	19.7	23.0	15.9	0	52
05-07-09	19.3	26.0	12.3	30	48
06-07-09	18.0	21.4	14.7	3.6	56
07-07-09	15.2	18.6	12.5	12.4	74
08-07-09	15.2	17.7	13.1	19.4	70
09-07-09	15.2	17.2	14.0	0.4	60
10-07-09	14.2	16.3	12.5	22	66
11-07-09	15.6	18.5	12.7	1.2	61
12-07-09	16.4	19.4	14.2	5.4	74
13-07-09	17.4	21.9	12.8	0	57
14-07-09	18.6	23.5	12.7	2.6	51
15-07-09	19.3	22.5	14.8	0.2	50
16-07-09	19.1	24.2	13.0	0	47
17-07-09	18.6	21.9	15.6	10.4	58
18-07-09	15.4	17.7	13.8	0.8	67
19-07-09	16.3	19.7	13.2	0	58
20-07-09	16.5	19.5	13.6	1.8	59
21-07-09	18.0	24.9	11.3	3.4	57
22-07-09	19.0	22.4	16.4	1.4	62
23-07-09	16.8	20.1	14.9	8.2	62
24-07-09	15.7	18.9	13.6	6.4	65
25-07-09	16.4	19.0	13.4	7	64
26-07-09	17.3	22.4	11.8	0	48
27-07-09	18.1	23.8	15.1	0.2	54
28-07-09	16.6	20.9	12.6	0	52
29-07-09	18.5	23.9	13.8	0	50
30-07-09	16.1	19.4	12.2	3.8	57
31-07-09	15.5	20.9	9.9	0	49
01-08-09	17.8	24.4	10.8	0	41
02-08-09	17.2	18.5	14.8	9	69
03-08-09	15.7	20.5	10.5	0	48
04-08-09	17.8	24.1	10.0	0	42
05-08-09	20.6	26.8	13.7	0	35
06-08-09	22.4	28.5	15.2	0	33
07-08-09	21.8	27.9	16.7	0	49
08-08-09	18.4	20.3	16.1	0	66
09-08-09	17.1	20.3	13.5	0	74
10-08-09	18.0	23.1	12.4	0	45
11-08-09	18.2	20.6	16.1	0.2	72
12-08-09	17.6	20.2	15.0	0.2	72
13-08-09	17.1	19.8	14.4	0	57
14-08-09	16.7	21.7	11.3	0	49

Appendix 3. Late blight assessments

Percentage of foliage destroyed by late blight per plot

plot	treatment	replication	3/7	6/7	10/7	16/7	20/7	27/7	3/8	10/8	13/8
1	K0	1	0,1	0,2	0,3	50	55	70	90	98	99
8	K0	2	0,001	0,005	0,05	40	60	65	95	99	100
14	K0	3	0,002	0,005	0,02	20	30	45	90	96	98
23	K0	4	0,01	0,01	0,01	30	40	60	98	99	99
3	K1	1	0,005	0,05	0,1	7	15	20	40	50	70
10	K1	2	0,001	0,005	0,1	5	4	4	30	40	45
13	K1	3	0,003	0,02	0,1	4	6	5	30	35	45
24	K1	4	0,002	0,01	0,02	5	8	5	25	35	45
6	K2	1	0,001	0,003	0,05	2	5	5	35	45	60
9	K2	2	0,01	0,05	0,1	5	8	12	40	40	50
15	K2	3	0,01	0,02	0,1	8	15	10	35	50	60
20	K2	4	0	0,004	0,1	6	8	8	35	45	55
4	K3	1	0,002	0,005	0,01	3	5	10	50	70	85
7	K3	2	0,002	0,1	0,1	5	15	10	55	70	85
16	K3	3	0	0,005	0,005	3	3	8	45	70	80
21	K3	4	0,003	0,01	0,03	4	5	8	45	60	75
5	K4	1	0,01	0,1	0,1	2	3	5	30	35	50
12	K4	2	0	0,002	0,01	3	3	3	40	45	45
17	K4	3	0,004	0,01	0,02	1	2	2	35	45	55
22	K4	4	0,001	0,002	0,002	1	2	3	40	50	55
2	K5	1	0,002	0,01	0,01	2	3	3	30	50	60
11	K5	2	0,002	0,006	0,02	5	8	15	40	40	50
18	K5	3	0,001	0,005	0,01	2	3	3	30	40	50
19	K5	4	0,004	0,01	0,01	7	10	7	40	50	70