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Results of potato fertilizer demonstrations in Pangalengan and Garut, Indonesia

Wet season 2014/2015 and dry season 2015

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vegIMPACT
Improved Vegetable Production and Marketing for small farmers to Increase the Food Security status and to promote Private Sector Development in Indonesia

vegIMPACT is a program financed by The Netherlands' Government promoting improved vegetable production and marketing for small farmers in Indonesia, contributing to the food security status and private sector development in Indonesia. The program builds on the results of previous joint Indonesian-Dutch horticultural development cooperation projects and aligns with recent developments in the horticultural private sector and retail in Indonesia. The program activities (2012 – 2016) include the Development of Product Market Combinations, Strengthening the Potato Sector, Development of permanent Vegetable Production Systems, Knowledge Transfer and Occupational Health.

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Executive summary

In Indonesia, the amount of nutrients applied to potato crops is relatively high. A farmer survey conducted in the main potato growing area in West-Java (Pangalengan and Garut) showed average applications of 232 kg N/ha and 305 kg P_2O_5/ha from organic manure plus average applications of 172 kg N/ha and 268 kg P_2O_5/ha from chemical fertilizers. Nutrient use may be reduced when optimum application levels are known. This report describes the results of three demo experiments to determine the optimum nitrogen and phosphorus fertilizer levels for potatoes in Pangalengan and Garut:

1. N-demo to show the response of potatoes (variety Granola) to nitrogen levels (0, 60, 120, 180, 240 kg N/ha) in the wet season 2014/2015, carried out both in Pangalengan and Garut.
2. NP-demo with four nitrogen levels (120, 160, 200, 240 kg N/ha) and two phosphate levels (0 and 250 kg P_2O_5/ha) in two potato varieties, Granola and Atlantic, in the dry season 2015 carried out both in Pangalengan and Garut.
3. P-demo to show the response of potatoes (variety Granola) to phosphate levels (0, 41, 85, 126, 167 kg P_2O_5/ha) in the dry season 2015 carried out both in Pangalengan and Garut.

Major findings of the N-demos were:

- No yield responses to N-fertilizer levels in Pangalengan due to the high percentages of wilted plants and rotten tubers.
- Tuber yields in Garut increased up to an application of 120 kg N/ha of chemical fertilizers and 15 ton/ha of chicken manure.
- The optimal N-application of chemical fertilizers for maximum yield of Granola in Garut was between 107 to 170 kg N/ha plus 15 tons/ha of chicken manure, depending on the method used to determine the optimal level, broken stick (linear plus plateau function) or quadratic plateau function.
- The N-surplus ranged from 170 to 379 kg N/ha in Garut. The N-surplus at an application rate of 120 kg N/ha was 210 kg N/ha.
- The apparent nitrogen recovery at an application of 120 kg N/ha in Garut was 32%.

Major findings of the NP-demos were:

- Yield differences related to variety only and no yield responses to N-fertilizer levels were found. These findings agree with the optimal N-application of 107 to 170 kg N/ha from chemical fertilizers plus 15 tons/ha manure in the N-demo of the wet season 2014/2015 in Garut.
- There was no effect of the applied P fertilizer (0 vs. 250 kg P_2O_5/ha) on potato yields in both Pangalengan and Garut.
- N-surplus ranged from 157 to 294 kg N/ha in Pangalengan and from 140 to 298 kg N/ha in Garut and was slightly lower than the surplus in the N-demo of the wet season 2014/2015 in Garut.
- P_2O_5-surplus ranged from 315 to 571 kg P_2O_5/ha in Pangalengan and from 395 to 625 kg P_2O_5/ha in Garut.

Major findings of the P-demos were:

- Granola yield continued to increase up to the highest P-application in Pangalengan which was not supported by increased P-removal and therefore not related to higher P-application rates.
- Granola yield increased up to an application of 85 kg P_2O_5/ha in Garut.
- The optimal P_2O_5-application of chemical fertilizers plus 350 to 417 kg P_2O_5/ha from chicken manure for maximum yield of Granola in Pangalengan was between 114 and 165 kg fertilizer P_2O_5/ha and in Garut between 104 and 126 kg fertilizer P_2O_5/ha, depending on the method used to determine the optimum level, broken stick (linear plus plateau function) or quadratic plateau function.
- The apparent phosphate recovery at harvest at an application of 126 kg P_2O_5/ha in Pangalengan and Garut was 5 and 2%, respectively.

From the three demonstrations it is concluded that:

- The optimal N-application of chemical fertilizers for maximum yield of Granola in Garut was between 107 to 170 kg N/ha plus 15 tons/ha of chicken manure.
- The contribution of chicken manure to the N-supply of potato is not yet clear.
- To improve fertilization the N-content of the applied chicken manure and the N-use efficiency from chicken manure needs to be known.
- The low apparent nitrogen recovery as well as the large N-surplus show room for the development and implementation of techniques to increase N-use efficiency.
- Although the majority of the phosphate in potato production is applied with organic manure, application of small amounts of phosphate through chemical fertilizer is essential for high potato yields in Pangalengan and Garut.
- The optimal phosphate application of chemical fertilizers for maximum yield of Granola in Pangalengan and Garut was found to be between 114 to 165 and 104 to 126 kg P_2O_5/ha plus 10 tons/ha chicken manure, respectively.
- The low apparent phosphate recovery as well as the large P-surplus show room for the development and implementation of techniques to improve phosphate use efficiency.

These demonstrations show promising perspectives for reducing nutrient inputs and associated costs in potato production while maintaining potato yields and potato quality in Pangalengan and Garut.

1. Introduction

In Indonesia, the amount of nitrogen applied to potato crops is relatively high. A survey conducted in the main potato growing area in West-Java under 20 farmers in Pangalengan and 20 farmers in Garut during the dry season of 2013 showed an average application of 304 kg N/ha from organic manure (range 158 – 473 kg N/ha) together with an average application of 172 kg N/ha from chemical fertilizers (range 63 – 350 kg N/ha) (De Putter*, et al.* 2014). In the wet season of 2013/2014, the same 40 potato farmers applied on average 203 kg N from organic manure (range 106 – 366 kg N/ha) and 178 kg N/ha from chemical fertilizers (range 58 – 321 kg N/ha (Van den Brink*, et al.* 2015b). High use of nitrogen fertilizers results in high costs for farmers, potentially reduces the financial benefits from potato production, and is undesired from an environmental point of view. Nitrogen fertilizer demos carried out in Garut and in Pangalengan during the dry season of 2014 showed the potential to reduce the use of organic manure and nitrogen fertilizer in two potato varieties, Granola and Atlantic, without lowering yield (Van den Brink*, et al.* 2015b).

Phosphorus is another important nutrient for the growth and development of potatoes beside nitrogen. Farmers in Pangalengan and Garut apply high amounts of phosphorus. A survey conducted in the wet season of 2013/2014 showed an average application of 305 kg P_2O_5/ha from organic manure (range 155 – 549 kg P_2O_5/ ha) together with an average application of 268 kg P_2O_5/ha from chemical fertilizers (range 73 – 537 kg P_2O_5/ha) (Van den Brink*, et al.* 2015b). In order to determine the optimum rate of nitrogen and phosphorus fertilizer on potatoes, the following three demos were carried out in Pangalengan and Garut:

- Demo fields to show the response of potatoes (variety Granola) to several nitrogen rates in the wet season 2014/2015 (N-demos), carried out in both Pangalengan and Garut.
- Demo fields with four levels of nitrogen fertilization and two levels of phosphate fertilization in two potato varieties, Granola and Atlantic in the dry season 2015 (NP-demos), carried out both in Pangalengan and Garut.
- Demo fields to show the response of potatoes (variety Granola) to phosphorus rates in the dry season 2015 (P-demos), carried out both in Pangalengan and Garut.

This report describes the results of the three demos, which were carried out within the framework of the vegIMPACT program. This four year program aims at increasing and promoting vegetable production and marketing among small farmers in Indonesia (www.vegimpact.com). The demos contribute to the achievement of four interrelated objectives of the program, which are improving the potato production, reduce nitrogen fertilizer use per unit product, reduce production costs per unit product and increase financial margins for farmers in Indonesia.

2. Materials and methods

2.1. N-demos in wet season 2014/2015

The N-demo in Pangalengan was planted on 29 October 2014, while the N-demo in Garut was planted on 20 November 2014. In both fields the variety Granola was used. The plots consisted of 6 rows of 20 plants each. The row distance was 0.75 m and the plant distance within rows was 0.30 m. The beds were covered with silver-coloured plastic mulch. At harvest four rows in the middle of each plot were harvested while the first and the last plants of these rows were not harvested. The net size of the harvested plot was 3 m (4 rows) x 5.4 m (18 plants per row), totalling 16.2 m^2. In total, five unique plots were laid out in the N-demos with four replications.

Fertilizer treatments are presented in Table 2.1. Four levels of nitrogen fertilization were included (0, 60, 120, 180 and 240 kg N from chemical fertilizer). Inorganic phosphate and potash fertilization was the same in all treatments. Phosphorus fertilizer as SP36 was applied at a rate of 275 kg P_2O_5/ha while potassium fertilizer as KCl was applied at a rate of 180 kg K_2O/ha.

Table 2.1. Treatments in N-demos in Pangalengan and Garut in the wet season 2014/ 2015.

Treatment	Organic manure (ton/ha)	N from chemical fertilizer (kg/ha)	P_2O_5 from chemical fertilizer (kg/ha)	K_2O from chemical fertilizer (kg/ha)
0 N	15	0	275	180
60 N	15	60	275	180
120 N	15	120	275	180
180 N	15	180	275	180
240 N	15	240	275	180

In both locations, the mineral content of organic manure (*ayam postal*) was analysed (Table 2.2). Also, soil samples were analysed from both demo fields (Table 2.3).

Table 2.2. Mineral percentage (fresh weight basis) of organic manure (ayam postal) applied to N-demos and amount of nutrients applied (kg/ha) in Pangalengan and Garut during the wet season 2014/2015.

	Pangalengan		Garut	
	%	Kg/ha	%	Kg/ha
Nitrogen (Kjeldahl)[1]	2.87	431	1.41	212
P_2O_5	2.36	354	3.17	476
K2O	2.55	383	1.91	287
C-organic	29.81	4472	15.92	2388
C/N-quotient	10.0	-	11.0	-
Dry matter	79.8	7977	62.5	9377

[1] Kjeldahl method analyses the organic N fraction.

Table 2.3. Chemical soil properties of the N-demo fields in Pangalengan and Garut during the wet season 2014/2015.

	Pangalengan	Garut
pH-KCl	4.9	5.6
N Kjeldahl (%)	0.54	0.45
P2O5 (ppm, Olsen)	284	390
K (ppm)	182	288
C-organic	4.7	4.3

Inorganic N was supplied as ZA (Ammonium Sulphate), P_2O_5 as SP36 (Super Phosphate) and K_2O as KCl. In each treatment 50% of the inorganic N was applied at planting and 50% four weeks after planting**.** All inorganic phosphate was applied as SP36 one day before planting.

At several moments during the growing season plant height and the percentage ground cover was estimated. Additionally, crop health and drought symptoms were observed. Control of pest and diseases was carried out as optimal as possible.

At 60 days after planting from each plot three plants were harvested and the dry matter content and the nitrogen content were determined of aboveground biomass and tubers. At harvest, from each plot the tubers of three plants were analysed on dry matter content and nitrogen content.

The N-demos were manually harvested in Pangalengan on 27 January 2015 and in Garut on 26 February 2015, i.e. at 89 and 98 days after planting, respectively in both locations. Tubers were classified into three grades: class > 100 gram, class 50-100 gram and class < 50 gram. Also the weight of rotten tubers was assessed.

Data of plant height, soil cover and yield were statistical analysed with ANOVA.

Additional calculations were made to calculate the optimal N-application rate for chemical fertilizers with the broken stick method and the quadratic plateau method (Cerrato and Blackmer 1990). The N available from manure was not included in these calculations.

2.2. NP-demos in dry season of 2015

NP-demos in Pangalengan and Garut were planted with the potato varieties Granola and Atlantic on 6 and 7 May 2015, respectively. The plots consisted of 6 rows of 20 plants each. The row distance was 0.75 m and the plant distance within rows was 0.30 m. The beds were covered with silver-coloured plastic mulch. At harvest four rows in the middle of each plot were harvested while the first and the last plants of these rows were not harvested. The net size of the harvested plot was 3 m (4 rows) x 5.4 m (18 plants per row), totalling 16.2 m^2. In total, twelve unique plots were laid out in the NP-demo with three replications.

Fertilizer treatments are presented in Table 2.4. Four levels of nitrogen fertilization were included (120, 160, 200 and 240 kg N/ha from chemical fertilizer) and two phosphate levels (0 and 250 kg P_2O_5/ha from chemical fertilizer). Inorganic potash fertilization was the same in all treatments.

Table 2.4. Treatments in NP-demos in Pangalengan and Garut during the dry season of 2015.

Treatment	Organic manure (ton/ha)	N from chemical fertilizer (kg/ha)	P_2O_5 from chemical fertilizer (kg/ha)	K_2O from chemical fertilizer (kg/ha)
120N/250P	10	120	250	200
160N/250P	10	160	250	200
200N/250P	10	200	250	200
240N/250P	10	240	250	200
160N/0P	10	160	0	200
200N/0P	10	240	0	200

In both locations, the mineral content of organic manure (Ayam postal) was analysed (Table 2.5). Also, from both demo fields soil samples were analysed (

Table 2.6).

Table 2.5. Mineral percentage (on the basis of fresh weight) of organic manure (ayam postal) applied and amount of nutrients applied (kg/ha) to NP-demos in Pangalengan and Garut during the dry season of 2015.

	Pangalengan		Garut	
	%	Kg/ha	%	Kg/ha
Nitrogen (Kjeldahl)[1]	1.57	157	1.37	137
P_2O_5	3.50	350	4.17	417
K_2O	1.91	191	1.74	174
C-organic	21.72	2172	16.27	1627
C/N-quotient	14.0	-	12.0	-
Dry matter	70.9	7092	57.7	5776

[1] Kjeldahl method analyses the organic N fraction.

Table 2.6. Chemical soil properties of the NP demo fields in Pangalengan and Garut during the dry season of 2015.

	Pangalengan	Garut
pH-KCl	4.4	5.8
N Kjeldahl (%)	0.62	0.37
P_2O_5 (ppm, Olsen)	705	405
K (ppm)	256	268
C-organic	5.8	3.5

Inorganic N was supplied as ZA (Ammonium Sulphate), P_2O_5 as SP36 (Super Phosphate) and K_2O as KCl. In each treatment 50% of the inorganic N was applied at planting and 50% four weeks after planting. All inorganic phosphate was applied as SP36 one day before planting at dosages depending on the treatment.

At several moments during the growing season plant height was monitored. Additionally, crop health and drought symptoms were observed. Control of pest and diseases was carried out as optimal as possible.

At 56 days after planting from each plot three plants were harvested and the dry matter content, nitrogen content and phosphate content were determined of aboveground biomass and tubers. At harvest, from each plot the tubers of three plants were analysed on dry matter content, nitrogen content and phosphate content.

The NP-demos in the dry season of 2015 were manually harvested in Pangalengan on 5 August 2015 and in Garut on 19 August 2015, i.e. at 91 and 104 days after planting, respectively in both locations. Tubers were classified into three grades: class > 100 gram, class 50-100 gram and class < 50 gram. Also the weight of rotten tubers was assessed.

Data of plant height, soil cover and yield were statistical analysed with ANOVA.

2.3. P-demos in the dry season of 2015

P-demos in Pangalengan and Garut were planted with the potato variety Granola on 13 and 15 May 2015, respectively. The plots consisted of 5 rows of 20 plants each. The row distance was 0.75 m and the plant distance within the rows was 0.30 m. The beds were covered with silver-coloured plastic mulch. At harvest four rows in the middle of each plot were harvested while the first and the last plants of these rows were not harvested. The net size of the harvested plot was 2.25 m (3 rows) x 5.4 m (18 plants per row), totalling 12.2 m^2. In total, five unique plots were laid out in the P-demo with four replications.

Fertilizer treatments are presented in Table 2.7. Five levels of phosphate fertilization were included (0, 41, 85, 126, 167 kg P_2O_5/ha from chemical fertilizer, equivalent to 0, 18, 37, 55 and 73 kg P/ha). Inorganic nitrogen (180 kg N/ha) and potash (200 kg K_2O)/ha) fertilization was the same in all treatments.

Table 2.7. Treatments in P-demos in Pangalengan and Garut during the dry season of 2015.

			Organic P_2O_5 in manure (kg/ha)	
Treatment	Organic manure (ton/ha)	P_2O_5 from chemical fertilizer (kg/ha)	Pangalengan	Garut
0 P	10	0	350	417
18 P	10	41	350	417
37 P	10	85	350	417
55 P	10	126	350	417
73 P	10	167	350	417

On both locations, the mineral content of organic manure (*Ayam postal*) was analysed (Table 2.8). Also, from both demo fields soil samples were analysed (Table 2.9).

Table 2.8. Mineral percentage (on the basis of fresh weight) of organic manure (Ayam postal) applied and amount of nutrients applied (kg/ha) to NP-demos in Pangalengan and Garut during the dry season of 2015.

	Pangalengan		Garut	
	%	Kg/ha	%	Kg/ha
Nitrogen (Kjeldahl)[1]	1.57	157	1.37	137
P_2O_5	3.50	350	4.17	417
K_2O	1.91	191	1.74	174
C-organic	21.72	2172	16.27	1627
C/N-quotient	14.0	-	12.0	-
Dry matter	70.9	7092	57.7	5776

[1] Kjeldahl method analyses the organic N fraction.

Table 2.9. Chemical soil properties of the P-demo fields in Pangalengan and Garut during the dry season of 2015.

	Pangalengan	Garut
pH-KCl	4.3	6.2
N Kjeldahl (%)	0.59	0.61
P_2O_5 (ppm, Olsen)	358.7	443.9
K (ppm)	52.0	358.4
C-organic	6.8	3.4

The phosphate fertilizer treatments as SP36 were applied one day before planting. The nitrogen fertilizer as Urea at a rate of 180 kg N/ha was applied in all plots at half dose one day before planting and the rest 30 days after planting. The potassium fertilizer as KCl was applied at a rate of 200 kg K_2O/ha one day before planting.

At several moments during the growing season plant height was measured. Additionally, crop health and drought symptoms were observed. Control of pest and diseases was carried out as optimal as possible.

At 56 days after planting from each plot three plants were harvested and the dry matter content and phosphate content were determined of aboveground biomass and tubers. At harvest, from each plot the tubers of three plants were analysed on dry matter content and phosphate content.

P-experiments were manually harvested in Pangalengan on 12 August 2015 and in Garut on 27 August 2015, i.e. at 98 and 104 days after planting, respectively. Tubers were classified into three grades: class > 100 gram, class 50-100 gram and class < 50 gram. Also the weight of rotten tubers was assessed.

Data of plant height, soil cover and yield were statistical analysed with ANOVA.

Additional calculations were made to calculate the optimal P_2O_5-application rate for chemical fertilizers with the broken stick method and the quadratic plateau method (Cerrato and Blackmer 1990). The P_2O_5 available from manure was not included in these calculations.

2.4. N available from manure

In all three demos chicken manure (*ayam postal*) was applied prior to planting of the potatoes. In the NP demo (section 2.2) and the P demo (section 2.3) the same type and amount of manure was used.

To estimate the plant available nitrogen from the manure in the three demos the carbon (C) mineralisation model of Yang and Janssen (1997) was used. This mono-component model has a time dependent mineralisation rate constant. The change of a substrate (manure) under mineralisation in soil is described as:

$$C_{tot}(t) = C_0 * \exp\left(-R_9 * f * t^{(1-S)}\right)$$

in which t is time; C_{tot} and C_0 are the quantity of organic C at time t and time zero in the substrate; R_9 (= 0.81, dimension t^{S-1}) and S (= 0.5, dimensionless) regression constants for farm yard manure derived from a large dataset by non-linear regression by Yang and Janssen (1997). The parameter f is a correction factor to correct effects of temperature on mineralization from the base temperature of 9°C to the average temperature during the growing seasons. The temperature was corrected according to Yang and Janssen (Yang and Janssen 2002):

$f = 2^{(T-9)/9}$ for $9 < T \leq 27$°C,
$f = 0.1*(T+1)$ for $-1 < T \leq 9$°C,
$f = 0$ for $T \leq -1$°C,
$f = 4$ for $27<T<35$°C

where *T* is temperature in °C. The average temperature during the growing seasons was 27.4 °C leading to a correction factor f of 4. From the C mineralization the nitrogen mineralization was derived based on the C:N ratio of the manure. The input parameters used are presented in Table 2.10.

Table 2.10. Input parameters for the model estimates on available nitrogen from manure applications in Pangalengan and Garut.

	Pangalengan		Garut	
Parameter	2014/15	2015	2014/15	2015
C-organic (%)	29.81	21.72	15.92	16.27
N-organic (%)	2.87	1.57	1.41	1.37
Length of growing season (days)	89	91	98	104

2.5. Weather data

Table 2.11 presents the rain fall and the number of rainy days in Pangalengan and Garut during the demos. The total rainfall in the period October 2014-February 2015 (wet season N demo) was 1981 mm in Garut and 1601 mm in Pangalengan. The total rainfall in the period May-August 2015 (dry season NP- and P-demo) was 208 mm in Garut and 99 mm in Pangalengan.

Table 2.11. Rainfall characteristics during the wet season 2014/2015 and during the dry season of 2015 in Pangalengan and Garut.

	Pangalengan		Garut	
Month	Precipitation (mm)	Number of days with rain	Precipitation (mm)	Number of days with rain
October 2014	6	3	82	6
November 2014	401	21	512	24
December 2014	570	29	725	25
January 2015	302	23	302	22
February 2015	323	17	360	23
March 2015	407	24	391	27
April 2015	191	23	373	25
May 2015	96	11	173	6
June 2015	0	0	35	2
July 2015	4	1	0	0
August 2015	0	0	0	0

3. Results

3.1. N available from manure

The total amount of nitrogen mineralized during the growing period ranged from 75 kg/ha in Garut, dry season to 235 kg/ha in Pangalengan wet season 2014/15 (Table 3.1). The percentage of available N from the applied chicken manure was on average 54%.

Table 3.1. The total amount of N applied with manure (kg/ha), the modelled mineralized amount of N (kg/ha) and the percentage of N mineralized in Pangalengan and Garut during the wet season 2014/15 and the dry season 2015.

	2014/15			2015		
Location	Total N-manure	Mineralized	%	Total N-manure	Mineralized	%
Pangalengan	431	235	54	157	82	52
Garut	212	116	55	137	75	55

3.2. N-demos in wet season 2014/2015

3.2.1. Pangalengan

Plant height at different moments during the growing period is presented in Table 3.2 and Figure 3.1 left. Differences between N-levels are very small. The only exception is treatment 60 N, which show a lower plant height than the other treatments. This is mainly due to a considerable lower plant height in one of the replicates.

Table 3.2. Plant height in N-demo in Pangalengan during the wet season 2014/2015.

	Days after planting							
Treatment	21	28	35	42	49	56	63	70
0 N	9.8	23.3	32.5	49.8	59.8	65.7	67.0	67.8
60 N	9.1	22.0	30.2	45.5	55.8	59.0	62.0	63.3
120 N	9.7	23.5	32.0	49.1	60.5	65.5	67.3	68.6
180 N	10.3	24.5	34.2	48.3	60.5	64.5	67.4	65.8
240 N	8.4	21.1	31.6	50.1	59.5	66.2	67.6	67.5
F. Prob	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	<0.10	<0.10
LSD 5%	-	-	-	-	-	-	4.6	4.1

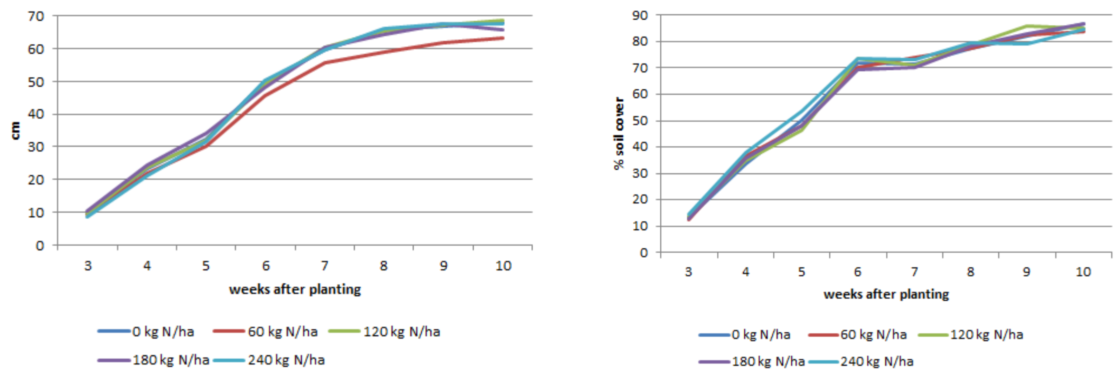


Figure 3.1. Plant height (left) and percentage soil cover (right) in N-demo of Pangalengan in the wet season 2014/2015.

Percentage soil cover at different moments during the growing period is presented in

Table 3.3 and Figure 3.1 right. Differences between N-levels are very small and not significant.

Table 3.3. Percentage soil cover in N-demo in Pangalengan during the wet season 2014/2015.

	Days after planting							
Treatment	21	28	35	42	49	56	63	70
0 N	13.3	33.7	50.1	72.0	71.5	77.4	82.0	86.9
60 N	12.3	36.4	48.0	70.0	74.2	77.4	82.6	83.9
120 N	13.8	35.1	46.4	73.6	71.1	78.7	85.9	84.9
180 N	12.8	36.0	48.1	69.3	70.1	78.3	83.1	86.6
240 N	14.7	38.0	53.6	73.5	73.3	79.6	78.9	84.4
F.Prob	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

The number of tubers per class is presented in Table 3.4 and Figure 3.2. Differences between treatments were small. In this demo many tubers were rotten, on average 25.1%.

Table 3.4. Number of tubers (#/m^2) per yield class in the N-demo in Pangalengan during the wet season 2014/2015.

	# of tubers per class (number/m^2)					
	Healthy tubers					
Treatment	<50 g	50-100 g	>100 g	Rotten tubers	Total # of healthy tubers	Total # of tubers (incl. rotten)
0 kg N	11.3	8.2	4.9	7.1	24.4	31.5
60 kg N	9.3	5.3	4.1	8.5	18.7	27.2
120 kg N	10.4	6.8	7.0	9.3	24.2	33.5
180 kg N	10.7	7.9	4.8	6.6	23.4	30.0
240 kg N	11.0	9.4	5.1	10.3	25.5	35.8
F.Prob	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

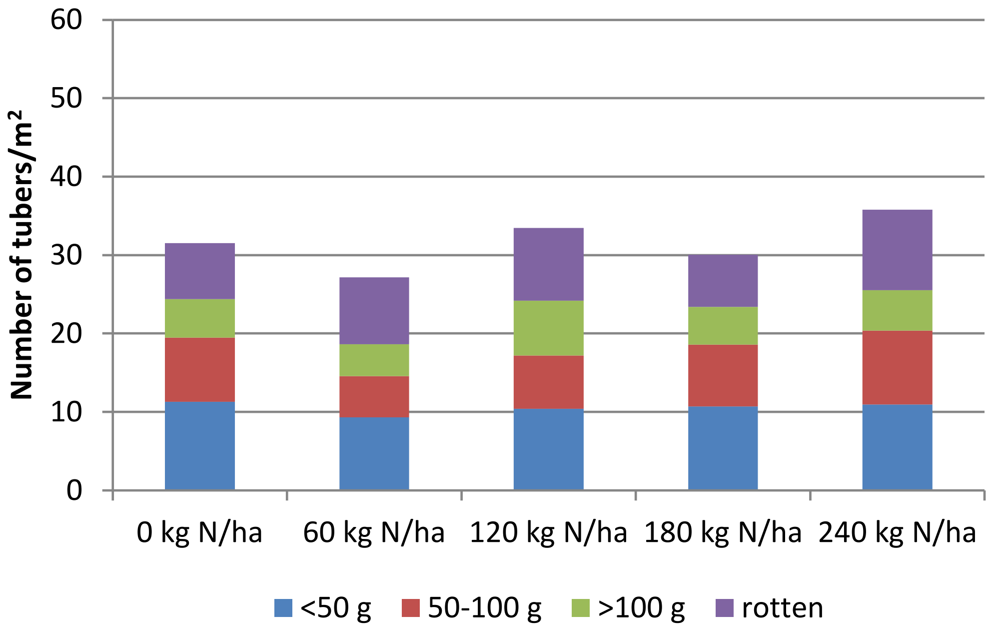


Figure 3.2. Number of tubers/m^2 per yield class in the N-demo in Pangalengan during the wet season 2014/2015.

Yield data presented in

Table 3.5 and Figure 3.3 show no significant differences between treatments; even the lowest N levels were not different from the highest N level. Overall, yields in this demo were very low, on average 15.6 ton healthy tubers/ha.

Table 3.5. Yield per class (ton/ha) and total yield (ton/ha) in the N-demo in Pangalengan during the wet season 2014/2015.

	Yield per class						
	Healthy tubers			Rotten	Total healthy yield		Total yield
Treatment	<50 g	50-100 g	>100 g	tubers	>50 g	Total healthy yield	(incl. rotten)
0 N	2.9	6.5	7.3	4.7	13.8	16.7	21.4
60 N	2.5	3.8	6.4	5.4	10.2	12.7	18.1
120 N	2.7	4.5	9.8	5.3	14.4	17.1	22.4
180 N	2.7	5.0	7.8	3.9	12.8	15.5	19.4
240 N	3.1	6.2	7.6	6.3	13.8	16.9	23.2
F.Prob	n.s.	<0.05	n.s.	n.s.	n.s.	n.s.	n.s.
LDS 5%	-	1.9	-	-	-	-	-

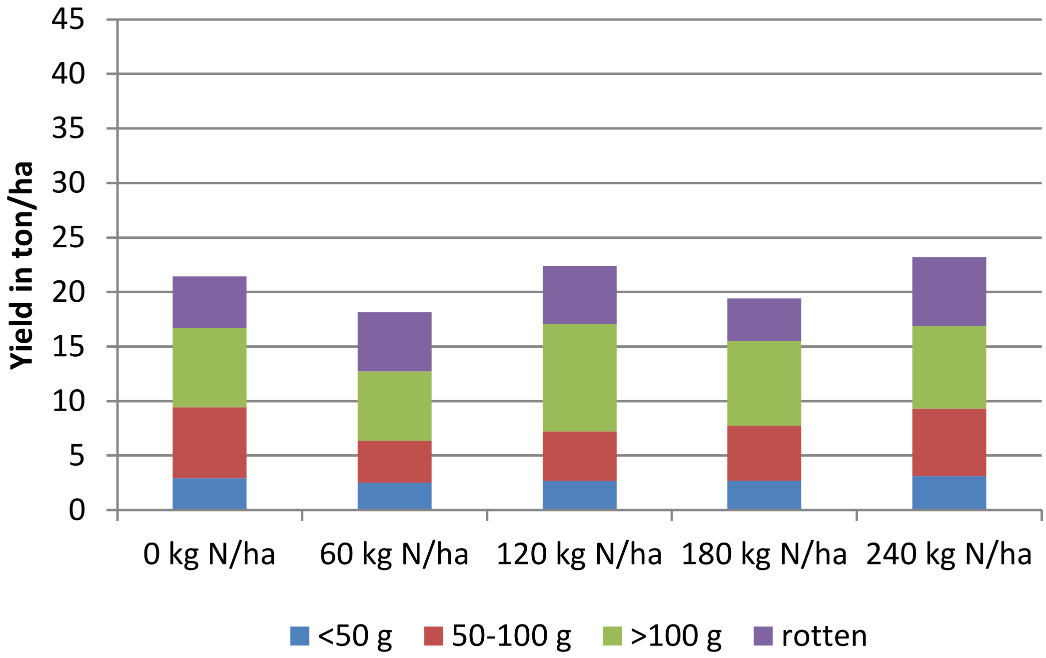


Figure 3.3. *Total yield and yield classes (ton/ha) in the N-demo in Pangalengan during the wet season 2014/2015.*

Table 3.6 presents the results of the dry matter content measurements at 60 days after planting and at harvest. Differences between N-levels were small.

Table 3.6. *Dry matter content (%) of leaves, stems, roots and tubers in N-demo in Pangalengan during the wet season 2014/2015.*

	60 Days after planting				Harvest
Treatment	Leaves	Stems	Roots	Tubers	Tubers
0 N	11.0	6.3	14.3	13.7	15.4
60 N	11.2	6.2	16.7	14.1	14.6
120 N	11.4	6.4	13.8	14.1	15.6
180 N	9.9	6.3	11.4	14.0	16.2
240 N	11.2	6.0	13.1	14.1	14.9
F.Prob	n.s.	n.s.	n.s.	n.s.	<0.10
LDS 5%	-	-	-	-	1.2

Table 3.7 presents the number of harvested plants and the N content of crop parts at 60 days after planting and at harvest. There were no clear differences between N-levels in the number of harvested plants and N content, but overall many plants showed disease symptoms.

Table 3.7. Number of harvested plants (#/m^2), percentage (%) of diseased plants at harvest and nitrogen content of leaves, stems, roots and tubers in N-demo in Pangalengan during the wet season 2014/2015.

				N-content (% in dry matter)				
	# of harvested plants		% diseased plants	60 days after planting				Harvest
Treatment	Healthy	Total	at harvest	Leaves	Stems	Roots	Tubers	Tubers
0 N	2.6	4.0	35.0	4.7	2.2	2.0	1.9	1.9
60 N	2.3	3.8	41.6	4.9	2.5	2.0	1.9	2.1
120 N	2.7	4.0	33.3	5.0	2.5	2.2	2.0	2.0
180 N	2.6	4.0	36.3	5.0	2.6	2.3	2.0	2.0
240 N	2.4	4.1	42.1	4.9	2.6	2.5	1.0	2.1
F.Prob	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

3.2.2. Garut

Plant height during the growing period is presented in Table 3.8 and Figure 3.4. Treatment 0 N had a significantly lower plant height than the other treatments from 35 days after planting till the end of the growing season. Also treatment 60 N had a lower plant length than the treatments with higher nitrogen applications, but this difference was not significant.

Table 3.8. Plant height in N-N-demo in Garut during the wet season 2014/2015.

	Days after planting							
Treatment	21	28	35	42	49	56	63	70
0 N	11.7	23.3	34.5	44.0	49.9	51.1	51.2	50.5
60 N	12.9	24.1	38.6	53.1	64.4	65.7	69.9	69.1
120 N	12.3	25.0	41.7	55.3	65.2	67.8	74.6	73.5
180 N	12.5	25.1	40.9	57.2	69.0	73.3	76.5	75.2
240 N	13.2	24.6	43.0	57.3	70.4	72.6	77.7	76.4
F.Prob	n.s.	n.s.	<0.05	<0.001	<0.001	<0.01	<0.001	<0.001
LSD 5%	-	-	5.1	4.6	6.9	9.0	8.7	9.2

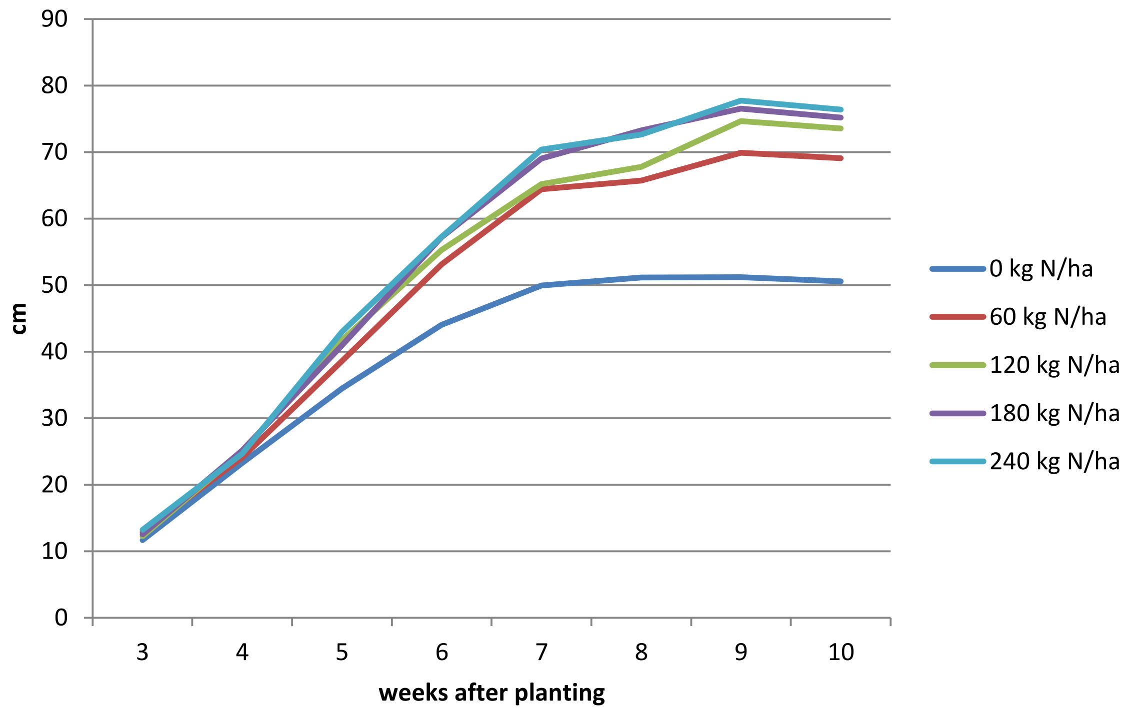


Figure 3.4. Plant height N-demo in Garut during the wet season 2014/2015.

Percentage soil cover at different moments is presented in Table 3.9 and Figure 3.5. Soil cover of treatment 0 N was significantly lower than the other treatments during the entire growing season. Also soil cover of 60 N was lower than the higher N level treatments, but this difference was not significant.

Table 3.9. Percentage soil cover in N-demo in Garut during the wet season 2014/2015.

	Days after planting							
Treatment	21	28	35	42	49	56	63	70
0 N	21.4	32.1	41.1	50.3	56.6	68.1	63.3	62.8
60 N	22.6	37.9	46.1	53.5	75.1	83.5	81.5	80.5
120 N	24.4	42.8	42.9	66.8	89.5	92.2	88.8	87.9
180 N	22.6	41.2	45.4	59.9	85.4	92.6	92.9	91.8
240 N	25.1	40.9	49.0	66.3	85.6	96.2	93.6	93.3
F.Prob	<0.01	<0.05	<0.10	<0.001	<0.001	<0.01	<0.01	<0.01
LSD 5%	1.7	6.1	5.7	6.7	7.5	15.0	13.4	13.9

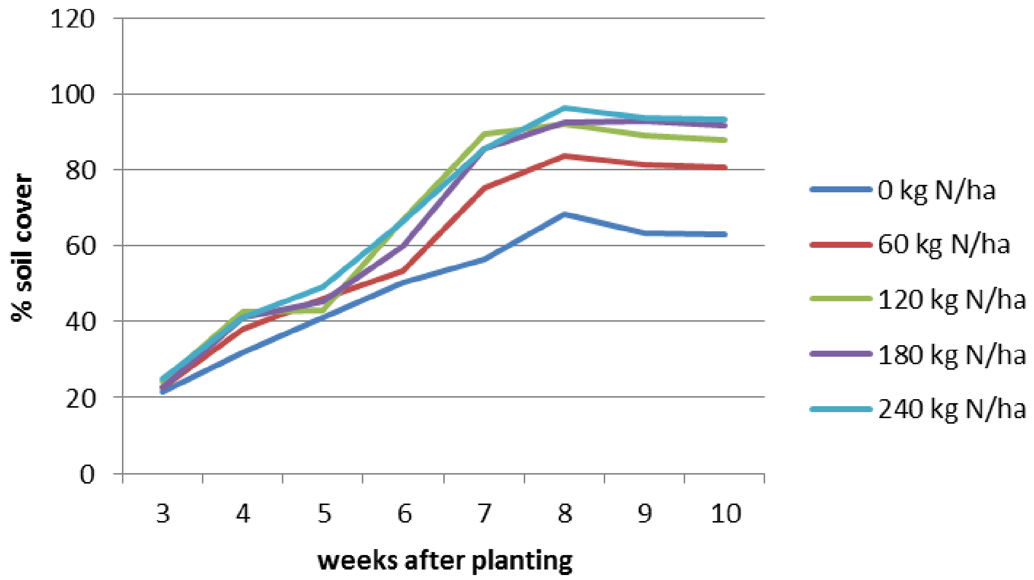


Figure 3.5. Percentage soil cover in N-demo in Garut during the wet season 2014/2015.

Figure 3.6. Researchers evaluating crop performance(left) and farmers evaluating yield (right)

Numbers of tubers per size class are presented in

Table 3.10 and Figure 3.7. Treatment 0 N had a significantly lower number of tubers than the other treatments. Treatment 60 N had less healthy tubers than the treatment with the highest N-application, 240 N and less total number of tubers (including rot) than treatments 120 N and 240 N.

Table 3.10. Number of tubers (#/m²) per yield class in the N-demo in Garut during the wet season 2014/2015.

Treatment	# of tubers per class				Total # of healthy tubers	Total # of tubers (incl. rotten)
	Healthy tubers			Rotten tubers		
	<50 g	50-100 g	>100 g			
0 N	15.5	10.0	6.1	0.8	31.6	32.4
60 N	16.0	12.0	11.4	0.9	39.3	40.2
120 N	19.5	15.9	11.2	0.5	46.6	47.1
180 N	19.6	15.8	8.9	0.7	44.3	45.0
240 N	19.3	17.5	10.4	0.4	47.2	47.6
F.Prob	n.s.	n.s.	n.s.	n.s.	<0.01	<0.01
LDS 5%	-	-	-	-	7.0	6.9

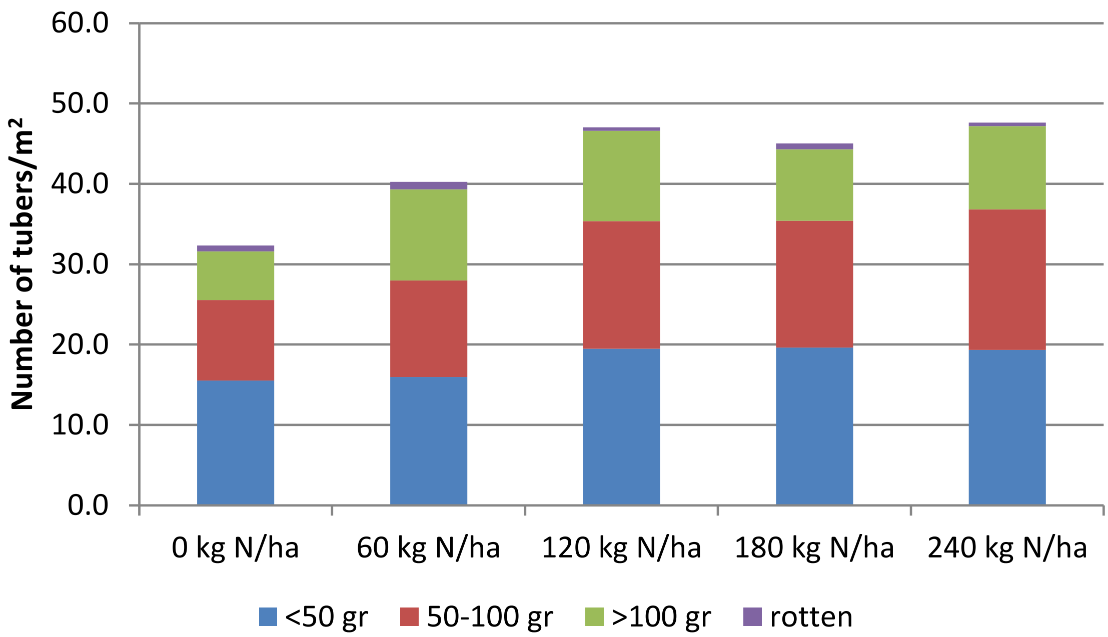


Figure 3.7. Number of tubers/m² per yield class in the N-demo in Garut during the wet season 2014/2015.

Yield data presented in

Table 3.11 and Figure 3.8 show large yield differences between N levels. Treatment 0 N yielded significantly less than the other treatments. Also treatment 60 N yielded lower than the other treatments, but this difference was not always significant. In general, yield levels in this demo were very high, up to 39 ton healthy tubers/ha.

Table 3.11. Yield classes (ton/ha) and total yield (ton/ha) in the N-demo in Garut during the wet season 2014/2015.

Treatment	Yield per class				Total healthy yield	Total healthy	Total yield
	Healthy tubers			Rotten			
	<50 g	50-100 g	>100 g	tubers	>50 g	yield	(incl. rotten)
0 N	4.6	8.6	8.0	0.4	16.6	21.2	21.6
60 N	4.8	9.7	15.2	0.4	24.9	29.8	30.2
120 N	6.1	14.8	16.1	0.3	30.8	36.9	37.1
180 N	6.1	14.0	13.6	0.3	27.6	33.7	34.0
240 N	6.1	16.2	16.7	0.2	32.9	39.0	39.1
F.Prob	n.s.	<0.10	<0.05	n.s.	<0.001	<0.001	<0.001
LDS 5%	-	6.2	5.7	-	5.2	5.2	5.4

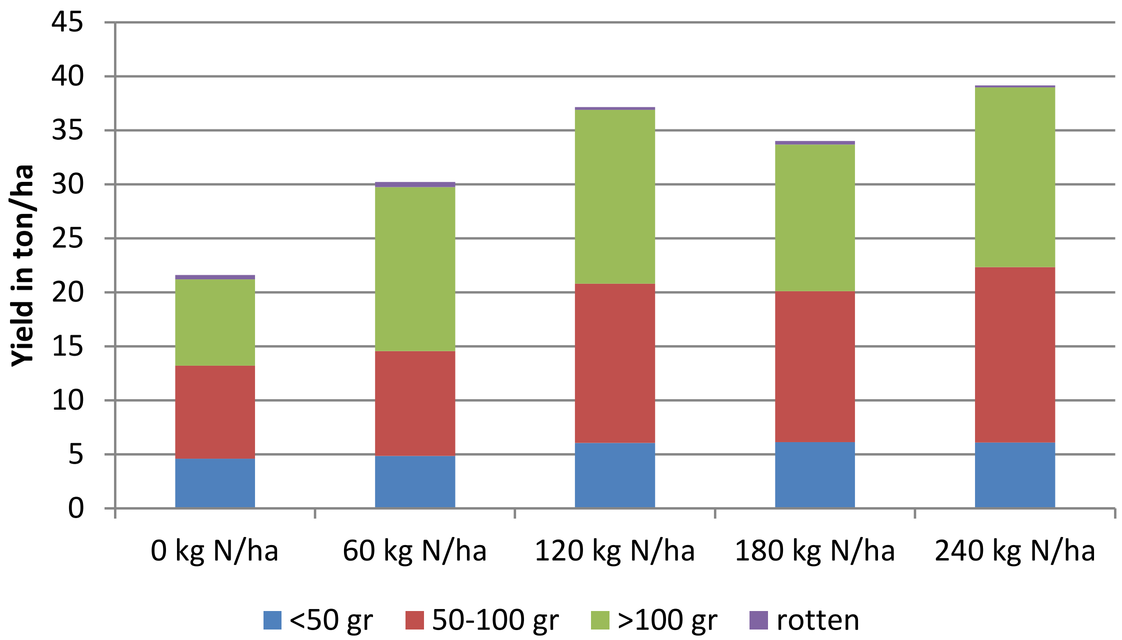


Figure 3.8. Total yield and yield classes (ton/ha) in the N-demo in Garut during the wet season 2014/2015.

Table 3.12 presents the dry matter content of crop parts at 60 days after planting and at harvest. Differences between N-treatments were small. At 60 days after planting the dry matter content in the leaves and stems in treatment 0 N was higher than in treatment 120 N and the same for treatments 60 N, 180 N and 240 N. No differences in dry matter content between treatments were found for roots or tubers.

Table 3.12. Dry matter content of leaves, stems, roots and tubers in N-demo in Garut during the wet season 2014/2015.

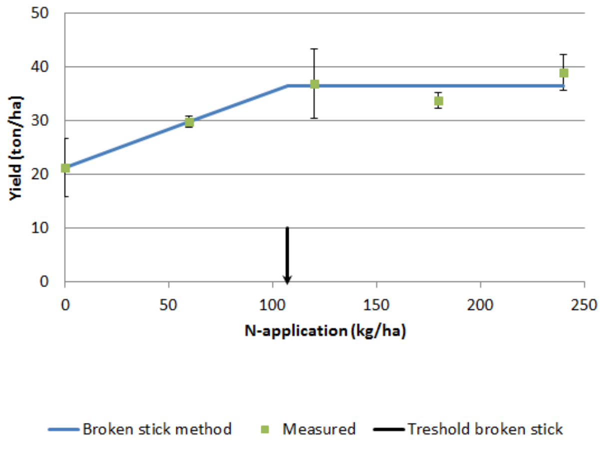
	60 Days after planting				Harvest
Treatment	Leaves	Stems	Roots	Tubers	Tubers
0 N	12.0	7.9	15.2	14.4	14.8
60 N	11.5	7.4	15.1	14.3	14.6
120 N	10.6	7.1	17.7	14.3	14.6
180 N	11.7	7.4	15.6	13.8	14.4
240 N	11.8	7.4	15.8	13.9	14.2
F.Prob	<0.10	<0.05	n.s.	n.s.	n.s.
LDS 5%	1.0	0.5	-	-	-

Table 3.13 presents the N content of crop parts at 60 days after planting and at harvest. There were no clear differences between N-treatments in number of harvested plants and there were few diseased plants. There were no clear differences between treatments in N content.

Table 3.13. Number of healthy and total harvested plants (#/m^2), percentage of diseased plants at harvest and the nitrogen content of leaves, stems, roots and tubers in N-demo in Garut during the wet season 2014/2015.

				N-content (% in dry matter)				
	# of harvested plants		% diseased plants	60 days after planting				Harvest
Treatment	Healthy	Total	at harvest	Leaves	Stems	Roots	Tubers	Tubers
0 N	4.1	4.3	4.3	4.5	2.0	1.7	1.4	1.3
60 N	4.2	4.4	2.5	4.8	2.2	2.0	1.4	1.4
120 N	4.2	4.4	3.5	4.7	2.2	2.1	1.6	1.4
180 N	4.3	4.4	2.4	4.8	2.5	2.1	1.7	1.5
240 N	4.3	4.4	2.4	4.9	2.6	2.1	1.7	1.3
F.Prob	<0.10	<0.10	n.s.	n.s.	n.s.	n.s.	n.s.	<0.05
LDS 5%	0.2	0.1	-	-	-	-	-	0.1

Figure 3.9 shows that the increase in yield above an application of 120 kg N/ha with chemical fertilizer is stagnating. The optimal N-application was estimated at 107 kg N/ha using the broken stick method and 170 kg/ha using the quadratic plateau method (Figure 3.9). The broken stick method is a conservative estimate of the optimal N-application whereas the quadratic plateau method has the tendency to overestimate the optimal N-application as this curve slowly approaches the break-even point. This calculation does not include the N available from manure applications. When the expected amount of mineralized N of 121 kg N/ha from manure is included the total optimal N application would be approximately 240 kg/ha.



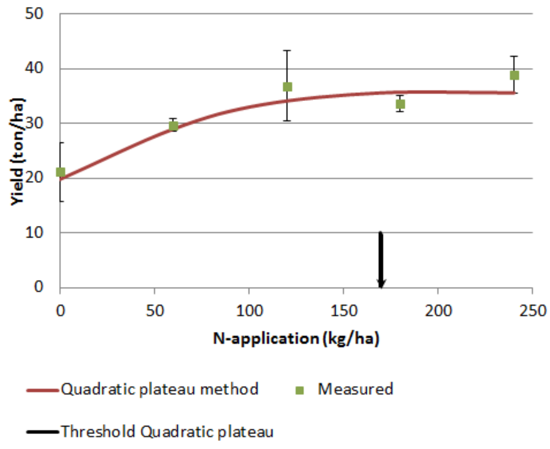


Figure 3.9. *The estimated optimal N-application using the broken stick method (left) and the quadratic plateau method (right), Garut, wet season 2014/2015. Arrow indicates the break-even point, that is where an extra application of 1 kg N/ha does not result in more yield. Vertical bars at measuring data indicate standard error of mean.*

3.3. NP-demos in dry season of 2015

3.3.1. Pangalengan

Plant height during the growing period is presented in Table 3.14. Differences between fertilizer treatments were generally smaller than between the varieties. Figure 3.10 shows the development of the plant height and clearly illustrates the more erect nature of Atlantic plants compared to Granola plants. No differences other than for variety were found.

Table 3.14. *Plant height in Granola and Atlantic in the NP-demo in Pangalengan during the dry season of 2015.*

	Days after planting								
Treatment	19	26	33	40	47	54	61	68	75
Granola 120N/250P	6.2	16.7	30.1	48.1	62.4	63.7	65.8	63.3	61.72
Granola 160N/250P	6.7	17.2	31.9	48.6	62.6	64.4	66.2	61.0	59.83
Granola 200N/250P	7.4	17.7	32.8	51.2	63.5	65.4	66.8	65.3	64.28
Granola 240N/250P	6.9	17.1	35.1	50.2	63.3	64.8	64.9	65.5	60.83
Granola 160N/0P	4.7	16.9	31.8	51.4	65.7	64.7	68.7	65.3	64.44
Granola 200N/0P	6.9	19.1	30.4	51.5	63.4	64.0	66.9	64.8	63.94
Atlantic 120N/250P	14.7	33.8	57.8	73.1	77.7	75.2	75.5	75.8	72.78
Atlantic 160N/250P	16.3	34.3	58.8	76.0	80.2	79.2	79.7	77.1	75.06
Atlantic 200N/250P	13.4	30.7	57.4	75.3	80.4	76.2	79.8	77.1	75.22
Atlantic 240N/250P	14.8	33.6	56.8	74.2	77.3	75.4	75.1	74.1	72.17
Atlantic 160N/0P	14.1	34.7	57.4	73.4	77.4	74.2	74.8	72.2	69.67
Atlantic 200N/0P	13.1	32.8	57.6	73.6	77.3	72.8	75.4	74.9	71.67
F.Prob	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
LSD 5%	3.3	3.3	6.2	6.0	6.8	6.2	6.3	6.0	6.1

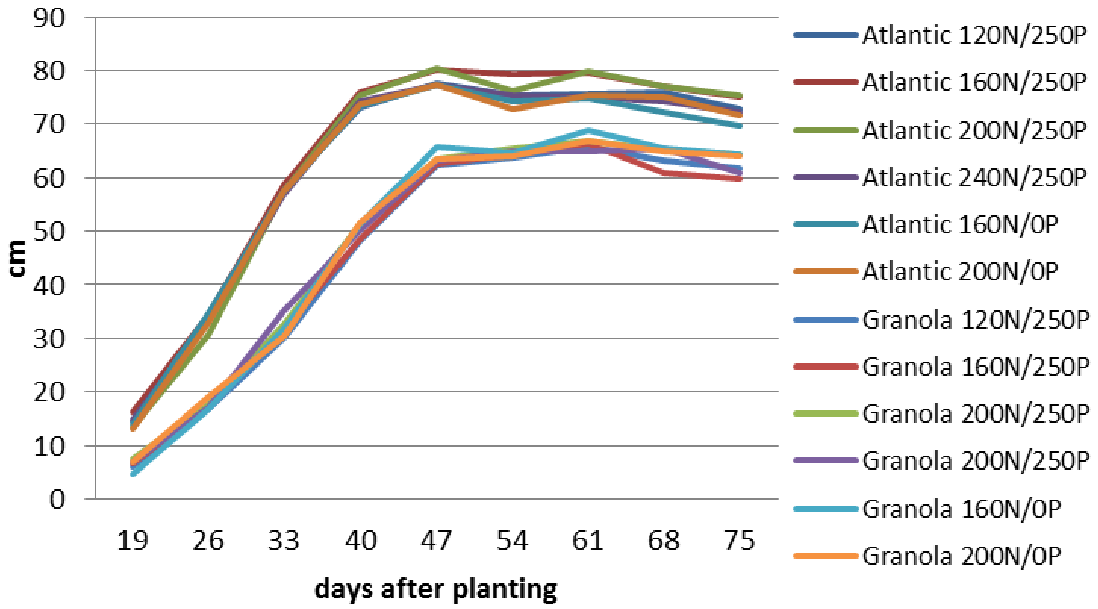


Figure 3.10. Plant height of Granola and Atlantic in the NP-demo in Pangalengan during the dry season of 2015.

Numbers of tubers (#/m^2) per class are presented in Table 3.15 and Figure 3.11 and show no effects of N treatments. The only difference found was between varieties. The number of tubers <50 g, 50-100 g, the total number of healthy tubers and total number of tubes was higher for Granola than for Atlantic. The percentage of rotten tubers was higher for Atlantic than for Granola. No difference in the number of tubers >100 g between Granola and Atlantic was found.

Table 3.15. Number of harvested tubers (#/m^2) of Granola and Atlantic in the NP-demo in Pangalengan in the dry season of 2015.

	# of tubers per class					
	Healthy tubers			Rotten	Total # of healthy	Total # of tubers
Treatment	<50 g	50-100 g	>100 g	tubers	tubers	(incl. rotten)
Granola 120N/250P	23.1	13.5	10.9	0.6	47.5	48.1
Granola 160N/250P	26.9	12.5	8.5	1.6	47.8	49.4
Granola 200N/250P	25.9	12.9	10.1	1.5	48.9	50.4
Granola 240N/250P	24.7	12.8	10.6	1.3	48.2	49.4
Average Granola	25.2 a	12.9 a	10.0	1.3 b	48.1 a	49.3 a
Atlantic 120N/250P	10.1	8.7	9.5	4.7	28.3	33.0
Atlantic 160N/250P	8.5	7.7	10.7	2.3	26.8	29.1
Atlantic 200N/250P	8.7	8.4	10.2	4.3	27.3	31.6
Atlantic 240N/250P	7.8	8.4	8.2	4.5	24.3	28.9
Average Atlantic	8.8 b	8.3 a	9.6	3.9 a	26.7 a	30.6 b
F.Prob variety	<0.001	<0.001	n.s.	0.014	<0.001	<0.001
LDS 5%	3.0	3.1	-	2.0	3.6	3.3

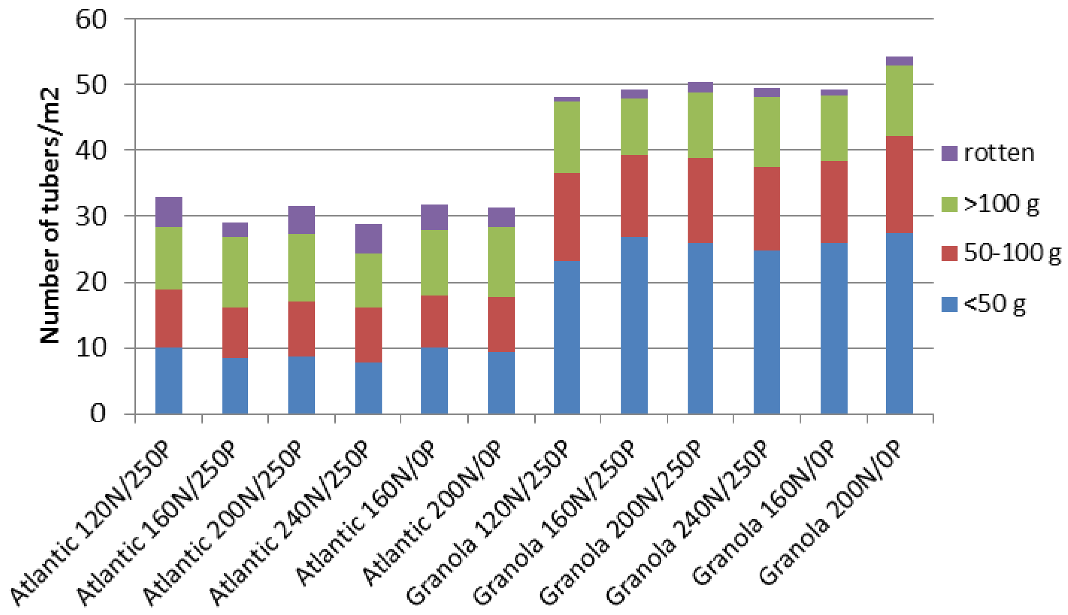


Figure 3.11. Number of tubers/m^2 per yield class of Granola and Atlantic in the NP-demo in Pangalengan during the dry season of 2015.

Yield data presented in Table 3.16 and Figure 3.12 show no effects of N treatments on yields. The only effects found were for varieties. Yields of Granola were significantly higher than yields of Atlantic, compare 34.5 tons/ha with 27.3 tons/ha. Both varieties had the same yield for yield class tubers > 100 g and for total healthy yield of tubers >50 g. Granola had a significant lower yield of rotten tubers which may indicate that the seed of Granola may have been healthier. In Atlantic, treatment 240N/250 P had the lowest yield, which could be due to the slightly lower number of harvested plants (Table 3.17).

Table 3.16. Yield per class (ton/ha) and total yield (ton/ha) of Granola and Atlantic in the NP-demo in Pangalengan during the dry season of 2015.

Treatment	Yield per class				Total healthy yield >50 g	Total healthy yield	Total yield (incl. rotten)
	Healthy tubers			Rotten tubers			
	<50 g	50-100 g	>100 g				
Granola 120N/250P	8.4	12.6	14.6	0.2	27.1	35.5	35.7
Granola 160N/250P	9.8	12.2	11.3	0.9	23.5	33.3	34.2
Granola 200N/250P	8.8	12.3	13.1	0.6	25.3	34.1	34.7
Granola 240N/250P	9.2	12.3	13.6	0.4	25.9	35.1	35.5
Average Granola	9.0 a	12.3 a	13.4	0.5 b	25.5	34.5 a	35.0 a
Atlantic 120N/250P	4.0	9.6	13.8	2.3	23.4	27.4	29.7
Atlantic 160N/250P	4.1	8.5	16.1	1.7	24.5	28.6	30.4
Atlantic 200N/250P	3.3	8.4	15.1	2.6	23.5	26.8	29.4
Atlantic 240N/250P	3.4	9.3	13.6	2.5	22.9	26.3	28.8
Average Atlantic	3.7 b	8.9 b	14.7	2.3 a	23.6	27.3 b	29.6 b
F.Prob variety	<0.001	<0.01	n.s.	<0.03	n.s.	<0.01	<0.01
LDS 5%	1.1	1.7	-	1.1	-	3.5	2.6

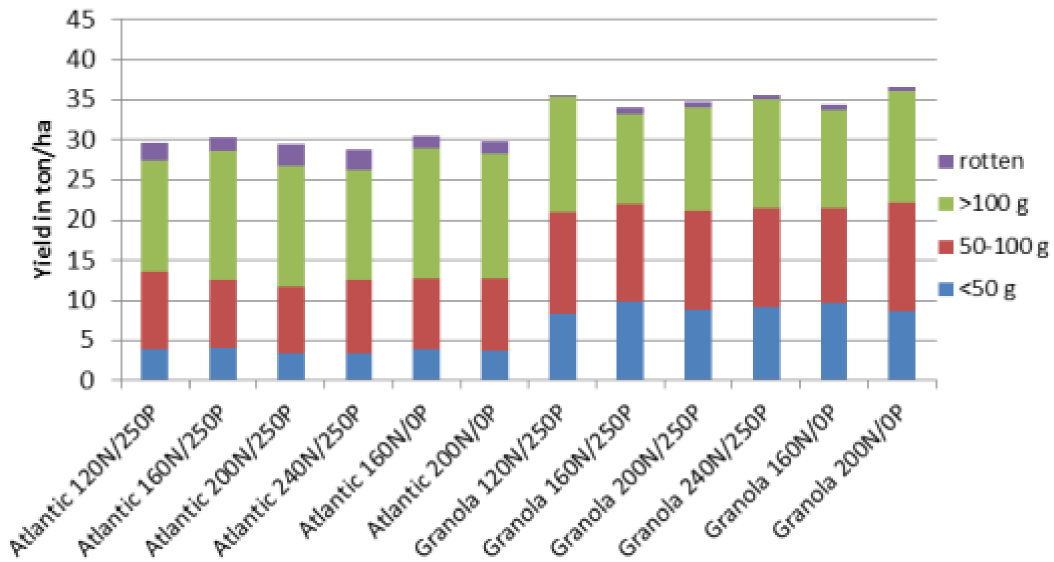


Figure 3.12. Total yield and yield per class (ton/ha) of Granola and Atlantic in the NP-demo in Pangalengan during the dry season of 2015.

Table 3.17 presents numbers of harvested plants and the dry matter content and N content of crop parts at 58 days after planting and harvest. N treatments had no effect but again, differences between varieties were found. Granola had a higher plant number at harvest (10% LSD) than Atlantic and a higher tuber dry matter content 58 days after planting where stems & leaves and tubers at harvest had lower dry matter contents than Atlantic.

Table 3.17. Number (#) of plants per m² at harvest, dry matter content of aboveground biomass and tubers in Granola and Atlantic in the NP-demo in Pangalengan during the dry season of 2015.

		Dry matter %		
		58 days after planting		Harvest
Treatment	# of plants/m^2	Stems and leaves	Tubers	Tubers
Granola 120N/250P	4.4	16.8	10.7	18.9
Granola 160N/250P	4.1	16.2	9.4	19.4
Granola 200N/250P	4.3	15.8	9.5	19.8
Granola 240N/250P	4.3	16.3	9.6	20.0
Average Granola	4.3 a	16.3 b	9.8 a	19.5 b
Atlantic 120N/250P	4.0	18.1	8.4	24.0
Atlantic 160N/250P	4.3	19.9	7.8	24.3
Atlantic 200N/250P	4.3	20.5	8.9	24.1
Atlantic 240N/250P	3.8	20.2	9.3	22.5
Average Atlantic	4.1 b	19.7 a	8.6 a	23.7 a
F.Prob variety	0.055	<0.001	0.015	<0.001
LDS 5%	0.15*	1.2	0.94	1.75

* LSD at 10%

Table 3.18 presents the N and P_2O_5 content of crop parts 58 days after planting and at harvest. There were no clear differences between N treatments and varieties in N and P_2O_5 content.

Table 3.18. Nitrogen and Phosphate content of aboveground biomass and tubers in Granola and Atlantic in the NP-demo in Pangalengan during the dry season of 2015.

	N-content (% in dry matter)			P_2O_5-content (% in dry matter)		
	58 days after planting		Harvest	58 days after planting		Harvest
Treatment	Stems and leaves	Tubers	Tubers	Stems and leaves	Tubers	Tubers
Granola 120N/250P	1.68	3.16	1.79	0.23	0.26	0.24
Granola 160N/250P	1.79	3.40	1.83	0.23	0.27	0.21
Granola 200N/250P	1.68	3.35	1.99	0.24	0.27	0.22
Granola 240N/250P	1.77	3.42	1.93	0.22	0.23	0.21
Average Granola	1.73	3.33	1.88	0.23	0.26	0.22
Atlantic 120N/250P	1.57	3.18	1.74	0.22	0.23	0.19
Atlantic 160N/250P	1.57	3.15	1.77	0.20	0.26	0.19
Atlantic 200N/250P	1.56	3.12	1.72	0.20	0.24	0.20
Atlantic 240N/250P	1.56	3.35	1.85	0.20	0.24	0.22
Average Atlantic	1.57	3.20	1.77	0.21	0.24	0.20
F.Prob variety	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

Table 3.19 shows the effect of 0 and 250 kg/ha phosphate fertilizer at 160 and 200 kg N/ha in Granola and Atlantic. Only small and not significant differences between yields of phosphate levels (0 *vs.* 250 kg P_2O_5/ha) were found in both varieties. However, differences between varieties were found: Granola had a higher yield for number of tubers and weight than Atlantic, and less rotten tubers. This is in line with findings described above.

Table 3.19. Effect of phosphate fertilization (0 vs. 250 kg P_2O_5/ha) at two N-application levels (160 and 200 kg/ha) on yield characteristics of Granola and Atlantic in Pangalengan during the dry season 2015. For units of parameters, see Table 3.15 – 3.18.

			Granola				Atlantic			
			160		200		160		200	
Characteristic			0	250	0	250	0	250	0	250
# of healthy tubers per class	<50 g		26.0	26.9	27.6	25.9	10.0	8.5	9.3	8.7
	50-100 g		12.4	12.5	14.6	12.9	7.9	7.7	8.5	8.4
	>100 g		9.9	8.5	10.6	10.1	10.1	10.7	10.5	10.2
Rotten tubers			1.0	1.6	1.5	1.5	3.7	2.3	3.1	4.3
Total # of healthy tubers			48.3	47.8	52.8	48.9	28.0	26.8	28.3	27.3
Total # of tubers (incl. rotten)			49.3	49.4	54.3	50.4	31.7	29.1	31.4	31.6
Yield per class	<50 g		9.7	9.8	8.6	8.8	3.9	4.1	3.8	3.3
	50-100 g		11.6	12.2	13.6	12.3	8.9	8.5	9.0	8.4
	>100 g		12.4	11.3	13.8	13.1	16.1	16.1	15.4	15.1
Rotten tubers			0.5	0.9	0.6	0.6	1.6	1.7	1.7	2.6
Total yield >50 g			24.1	23.5	27.5	25.3	25.0	24.5	24.4	23.5
Total healthy yield			33.8	33.3	36.1	34.1	28.9	28.6	28.2	26.8
Total yield (incl. rotten)			34.3	34.2	36.7	34.7	30.5	30.4	29.9	29.4
N-content (% dry in matter)	58 days after planting	Stems & leaves	1.81	1.79	1.63	1.68	1.66	1.57	1.59	1.56
		Tubers	3.33	3.4	3.29	3.35	3.28	3.15	3.03	3.11
	Harvest	Tubers	1.85	1.83	2.00	1.99	1.79	1.77	1.75	1.72
P-content (% dry matter)	58 days after planting	Stems & leaves	0.24	0.23	0.26	0.24	0.20	0.2	0.21	0.2
		Tubers	0.26	0.27	0.26	0.27	0.25	0.26	0.23	0.24
	Harvest	Tubers	0.23	0.21	0.22	0.22	0.20	0.19	0.18	0.20
# of plants/m^2			4.4	4.1	4.4	4.3	4.3	4.3	4.2	4.3
Dry matter %	58 days after planting	Stems & leaves	17.1	16.2	16.3	15.8	19.0	19.9	19.3	20.5
		Tubers	9.8	9.4	9.9	9.5	8.3	7.8	9.0	8.9
	Harvest	Tubers	18.5	19.4	19.9	19.8	26.7	24.3	24.3	24.1

Figure 3.13. Overview of the NP-demo in Garut (left) and evaluation of the yield (right).

3.3.2. Garut

Plant heights during the growing season are shown in Table 3.20 and Figure 3.14. A similar pattern is shown as in Pangalengan, i.e. Atlantic is much taller than Granola.

Table 3.20. Plant height in Granola and Atlantic in the NP-demo in Garut during the dry season of 2015.

	Days after planting								
Treatment	19	27	34	41	48	55	62	69	76
Granola 120N/250P	6.3	16.8	45.6	54.2	46.7	50.7	56.7	56.7	51.2
Granola 160N/250P	5.6	15.7	33.2	49.8	53.1	62.8	56.1	56.5	55.6
Granola 200N/250P	6.0	16.3	34.0	47.1	50.6	54.6	57.2	56.9	60.9
Granola 240N/250P	5.7	18.3	34.3	51.6	54.9	56.9	59.9	59.8	56.7
Granola 160N/0P	6.3	15.7	33.6	38.2	40.6	47.3	52.9	52.5	46.8
Granola 200N/0P	8.3	17.3	33.2	44.2	47.3	47.9	52.7	53.5	52.3
Atlantic 120N/250P	15.3	26.8	63.3	76.7	79.8	90.4	99.0	99.3	96.8
Atlantic 160N/250P	15.6	35.3	62.5	74.9	79.2	87.1	93.5	94.7	96.7
Atlantic 200N/250P	15.1	34.4	63.4	80.7	84.8	93.2	94.9	95.7	98.0
Atlantic 240N/250P	14.8	37.0	63.7	83.4	85.2	95.8	95.1	95.2	98.2
Atlantic 160N/0P	13.1	30.8	60.8	79.1	83.5	84.3	89.7	90.3	95.3
Atlantic 200N/0P	16.3	34.2	62.1	79.4	83.3	96.1	93.9	94.3	94.3
F.Prob	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
LSD 5%	4.0	6.9	11.0	15.2	14.5	14.7	14.4	14.7	15.8

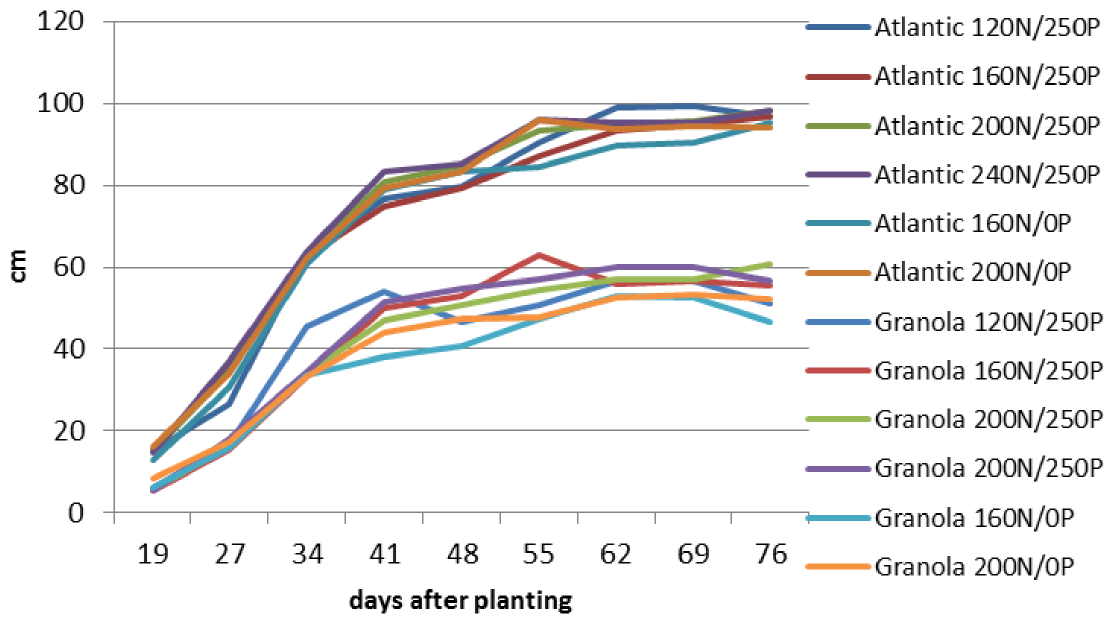


Figure 3.14. Plant height of Granola and Atlantic in the NP-demo in Garut during the dry season of 2015.

The number of tubers per yield class is shown in Table 3.21 and Figure 3.15. The difference between Granola and Atlantic in number of tubers is smaller than in Pangalengan (Table 3.16) and not significant.

Table 3.21. Number of harvested tubers (#/m²) of Granola in the NP-demo in in Garut in the dry season of 2015.

	# of tubers per class					
	Healthy tubers			Rotten	Total # of healthy	Total # of tubers
Treatment	<50 g	50-100 g	>100 g	tubers	tubers	(incl. rotten)
Granola 120N/250P	18.1	8.9	9.2	1.8	36.2	38.0
Granola 160N/250P	13.2	10.5	8.6	2.3	32.2	34.6
Granola 200N/250P	17.5	11.3	10.5	1.7	39.2	41.0
Granola 240N/250P	18.9	11.1	7.2	2.2	37.2	39.4
Average Granola	16.9	10.4	8.9	2.0	36.2	38.2
Atlantic 120N/250P	7.0	12.1	9.6	2.0	28.6	30.6
Atlantic 160N/250P	6.3	14.9	10.3	2.3	31.5	33.8
Atlantic 200N/250P	5.7	12.8	8.8	0.9	27.3	28.2
Atlantic 240N/250P	6.3	12.3	8.9	1.5	27.5	29.0
Average Atlantic	6.3	13.0	9.4	1.7	28.7	30.4
F.Prob variety	<0.001	0.078	n.s.	n.s.	0.014	0.036
LDS 5%	3.4	-	-	-	5.69	5.67

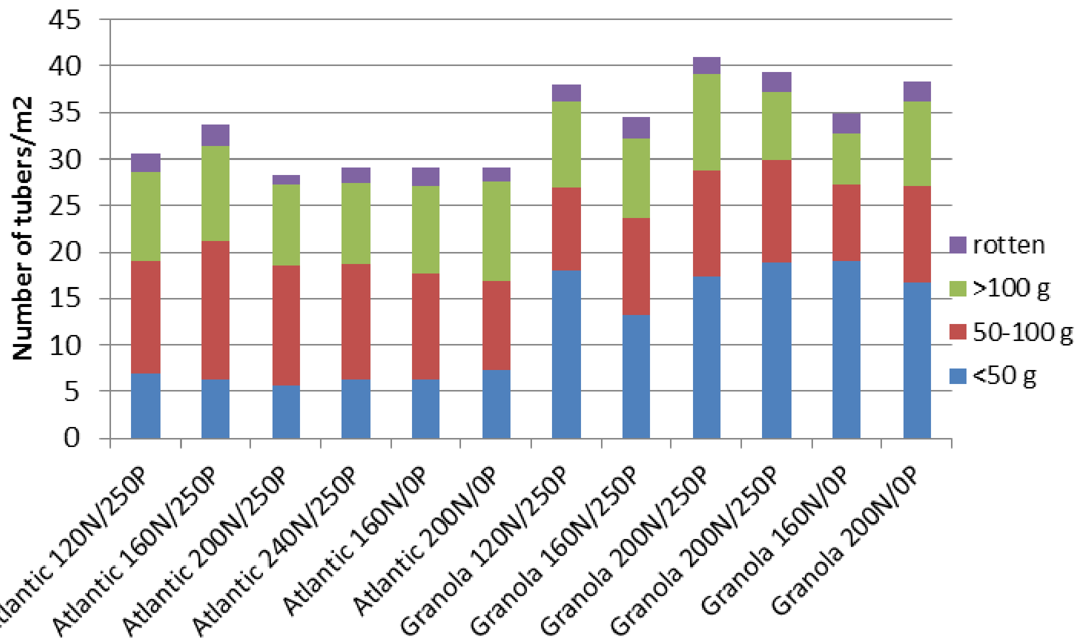


Figure 3.15. Number of tubers/m² per yield class of Granola and Atlantic in the NP-demo in Garut during the dry season of 2015.

In Table 3.22 and Figure 3.16 potato yields per size class are shown. In general, Atlantic yields were higher than Granola yields at the same N level, but the difference was not always significant. Within both varieties, yield differences between nitrogen levels and also between phosphate levels were not significant. In both varieties, the yield of treatment 160 N/0P was lowest, but not significant.

Table 3.22. Yield classes (ton/ha) and total yield (ton/ha) of Granola and Atlantic in the NP-demo in Garut during the dry season of 2015.

	Yield per class						
	Healthy tubers			Rotten	Total healthy	Total healthy	Total yield
Treatment	<50 g	50-100 g	>100 g	tubers	yield >50 g	yield	(incl. rotten)
Granola 120N/250P	6.1	9.5	14.1	1.2	23.5	29.6	30.8
Granola 160N/250P	6.9	9.5	13.3	1.5	22.8	29.7	31.2
Granola 200N/250P	6.2	9.6	16.1	1.0	25.7	31.9	32.9
Granola 240N/250P	7.0	10.9	11.8	1.3	22.7	29.7	31.0
Average Granola	6.6 a	9.9 b	13.8 b	1.2 b	23.7 b	30.2 b	31.5
Atlantic 120N/250P	3.1	15.6	21.2	2.6	36.8	39.9	42.5
Atlantic 160N/250P	3.2	14.9	23.3	2.8	38.2	41.5	44.3
Atlantic 200N/250P	2.8	15.6	21.4	1.1	37.0	39.8	41.0
Atlantic 240N/250P	2.8	15.9	20.0	1.9	35.9	38.6	40.6
Atlantic 160N/0P	2.9	11.9	21.2	2.6	33.2	36.1	38.7
Average Atlantic	3.0 b	15.5 a	21.5 a	2.1 a	37.0 a	39.9 a	42.1
F.Prob variety	<0.001	<0.01	<0.001	0.06	<0.001	<0.001	<0.001
LDS 5%	0.85	2.55	3.67	0.87*	4.67	4.8	4.97

* LSD at 10%

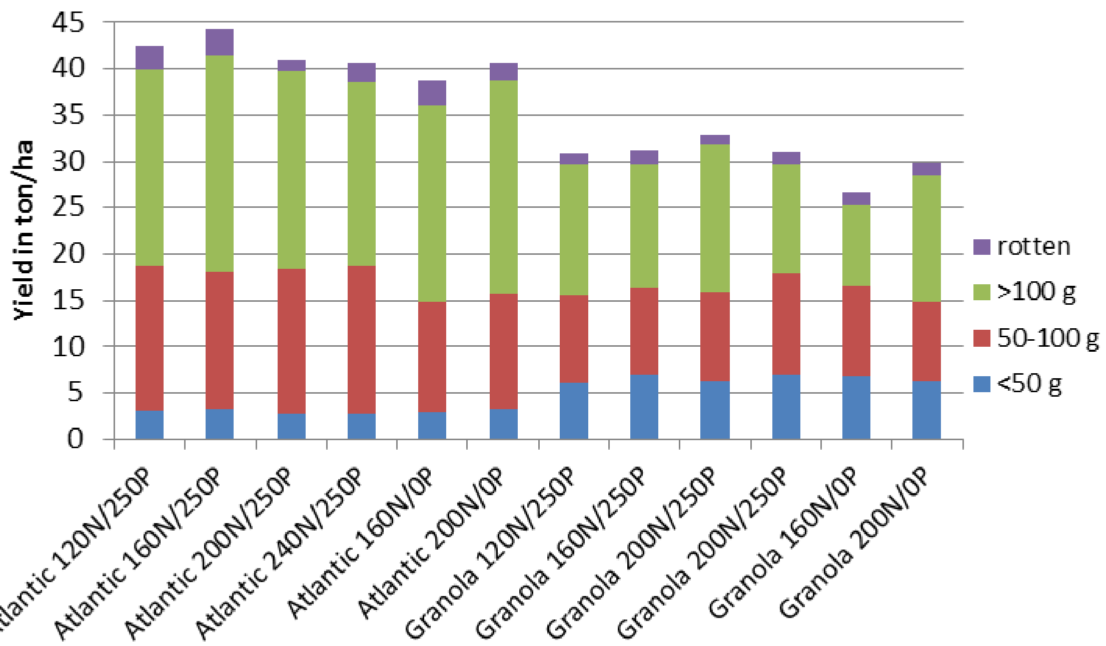


Figure 3.16. Total yield and yield classes (ton/ha) of Granola and Atlantic in the NP-demo in Garut during the dry season of 2015.

Table 3.23 presents numbers of harvested plants and the dry matter content of crop parts at 56 days after planting and at harvest. Between treatments there were no clear differences in plant number. Dry matter content of Atlantic tubers was higher than in Granola, but differences across N-levels and P_2O_5-levels were not significant.

Table 3.23. Number (#) of plants per m^2 at harvest, dry matter content of aboveground biomass and tubers in NP-demo in Garut during the dry season of 2015.

		Dry matter %		
		56 days after planting		Harvest
Treatment	# plants/m^2	Stems and leaves	Tubers	Tubers
Granola 120N/250P	4.1	10.8	16.5	17.4
Granola 160N/250P	4.3	9.9	15.5	16.8
Granola 200N/250P	4.2	9.2	17.8	18.0
Granola 240N/250P	4.1	10.5	16.2	17.5
Average Granola	4.2	10.1 a	16.5 b	17.4 b
Atlantic 120N/250P	4.1	8.1	19.5	22.8
Atlantic 160N/250P	4.3	8.4	18.9	22.7
Atlantic 200N/250P	4.1	8.0	19.1	23.0
Atlantic 240N/250P	4.1	8.2	19.2	22.8
Average Atlantic	4.1	8.2 b	19.1 a	22.8 a
F.Prob variety	n.s.	<0.001	<0.001	<0.001
LDS 5%	-	0.86	0.86	0.53

Table 3.24 shows the results of the N and P_2O_5 content measurements at 56 days after planting and at harvest. There were no differences between treatments.

Table 3.24. Nitrogen and Phosphate content of aboveground biomass and tuber in Granola and Atlantic in the NP-demo in Garut during the dry season of 2015.

	N-content (% in dry matter)			P_2O_5-content (% in dry matter)		
	56 days after planting		Harvest	56 days after planting		Harvest
Treatment	Stems and leaves	Tubers	Tubers	Stems and leaves	Tubers	Tubers
Granola 120N/250P	3.94	1.74	1.67	0.23	0.22	0.21
Granola 160N/250P	3.86	1.52	1.38	0.22	0.21	0.22
Granola 200N/250P	4.01	1.72	1.63	0.21	0.22	0.21
Granola 240N/250P	3.80	1.83	1.53	0.22	0.21	0.21
Average Granola	3.9	1.7	1.6	0.2	0.2	0.2
Atlantic 120N/250P	3.59	1.57	1.29	0.23	0.21	0.2
Atlantic 160N/250P	3.65	1.64	1.40	0.21	0.22	0.2
Atlantic 200N/250P	3.61	1.57	1.50	0.23	0.23	0.2
Atlantic 240N/250P	3.76	1.90	1.33	0.22	0.21	0.2
Average Atlantic	3.7	1.7	1.4	0.2	0.2	0.2
F.Prob	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

Table 3.25. Effect of phosphate fertilization (0 vs. 250 kg P_2O_5/ha) at two N-application levels (160 and 200 kg/ha) on parameters measured in Granola and Atlantic in Garut during the dry season 2015. For units of parameters, see Table 3.21 - Table 3.24.

			Granola				Atlantic			
			160		200		160		200	
Characteristics			0	250	0	250	0	250	0	250
# of healthy tubers per class	<50g		19.0	13.2	16.7	17.5	6.4	6.3	7.3	5.7
	50-100 g		8.2	10.5	10.5	11.3	11.4	14.9	9.6	12.8
	>100 g		5.5	8.6	9.1	10.5	9.4	10.3	10.8	8.8
Rotten tubers			2.2	2.4	2.2	1.8	2.1	2.3	1.5	0.9
total # of healthy tubers			32.7	32.2	36.3	39.2	27.1	31.5	27.7	27.3
total # of tubers (incl. rotten)			34.9	34.6	38.4	41.0	29.2	33.8	29.2	28.2
Yield per class	<50g		6.8	6.9	6.3	6.2	3.0	3.2	3.3	2.8
	50-100 g		9.8	9.5	8.6	9.6	11.9	14.9	12.3	15.6
	>100 g		8.8	13.3	13.6	16.1	21.2	23.3	23.1	21.4
Rotten tubers			1.3	1.5	1.4	1.0	2.6	2.9	1.9	1.2
Total yield >50 g			18.6	22.8	22.2	25.7	33.2	38.2	35.4	37.0
Total healthy yield			25.4	29.7	28.5	31.9	36.1	41.5	38.7	39.8
Total yield (incl. rotten)			26.6	31.2	29.9	32.9	38.7	44.3	40.6	41.0
N-content (% dry in matter)	58 days after planting	Stems & leaves	4.00	3.86	3.90	4.01	3.61	3.65	3.90	3.61
		Tubers	1.77	1.52	1.72	1.72	1.62	1.64	1.64	1.57
	Harvest	Tubers	1.59	1.38	1.41	1.63	1.21	1.40	1.34	1.50
P-content (% dry in matter)	58 days after planting	Stems & leaves	0.24	0.22	0.24	0.21	0.22	0.21	0.25	0.23
		Tubers	0.20	0.21	0.22	0.22	0.21	0.22	0.23	0.23
	Harvest	Tubers	0.20	0.21	0.22	0.21	0.19	0.20	0.20	0.20
# of plants/m^2			4.1	4.3	4.2	4.2	4.1	4.3	4.1	4.1
Dry matter %		Stems & leaves	10.5	9.9	10.8	9.2	7.8	8.4	8.1	8.0
	58 days after planting	Tubers	15.9	15.5	16.3	17.8	19.6	18.9	18.4	19.1
	Harvest	Tubers	16.9	16.8	16.8	18.0	22.2	22.7	23.0	23.0

3.4. P-demos in the dry season of 2015

3.4.1. Pangalengan

Plant heights during the growing season are presented in Table 3.26 and

Figure 3.17. Differences between P_2O_5-levels were very small.

Table 3.26. Plant heights in the P-demo in Pangalengan during the dry season of 2015.

	Days after planting								
Treatment	22	29	36	43	50	57	63	70	77
0 P	5.3	18.2	27.4	39.5	39.8	45.9	45.4	44.5	42.3
18 P	5.9	19.7	27.7	41.3	41.8	46.3	45.9	43.0	43.6
37 P	9.0	17.8	28.9	41.8	41.4	46.5	46.4	45.0	46.6
55 P	7.5	19.3	29.9	42.0	42.0	46.3	46.1	43.9	42.1
73 P	6.1	19.4	29.5	42.2	41.8	47.5	46.9	46.6	45.2

F.Prob	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

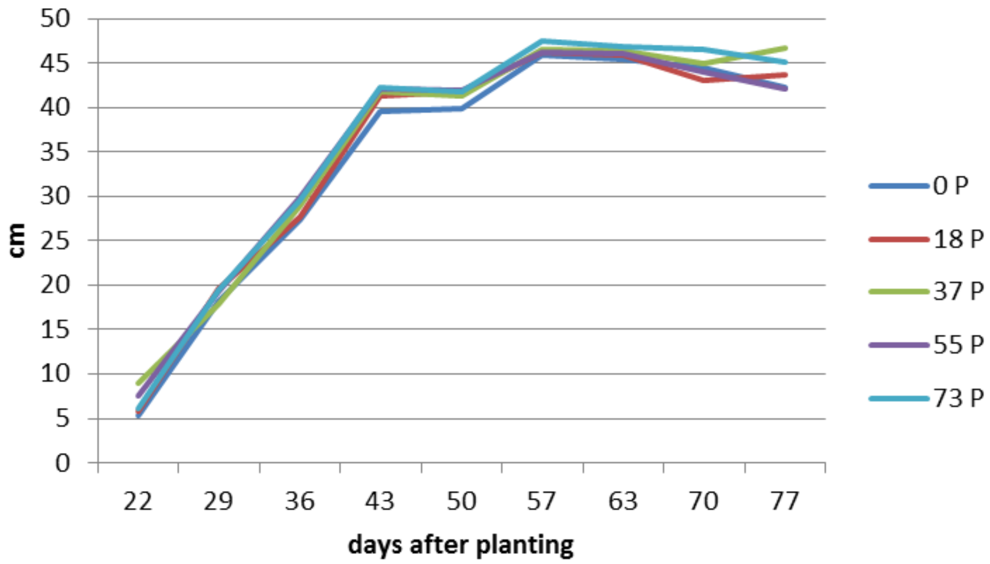


Figure 3.17. Plant heights in the P-demo in Pangalengan during the dry season of 2015.

The number of tubers per class is shown in Table 3.27 and Figure 3.18. There are no clear differences between fertilizer treatments in the number of tubers. Treatment 0 P tends to have the lowest number of tubers.

Table 3.27. Number of tubers (#/m^2) in the P-demo in Pangalengan during the dry season of 2015.

	# of tubers per class					
	Healthy tubers					Total # of tubers
Treatment	<50 g	50-100 g	>100 g	Rotten tubers	Total # of healthy tubers	(incl. rotten)
0 P	28.6	10.9	5.4	0.7	44.9	45.6
18 P	33.0	13.6	4.5	1.0	51.1	52.0
37 P	29.6	18.0	4.4	0.8	52.0	52.8
55 P	27.7	13.5	5.9	1.0	47.1	48.1
73 P	25.6	15.0	5.5	1.1	46.0	47.1
F.Prob	n.s.	<0.05	n.s.	n.s.	<0.10	<0.10
LDS 5%	-	3.6	-	-	5.7	5.6

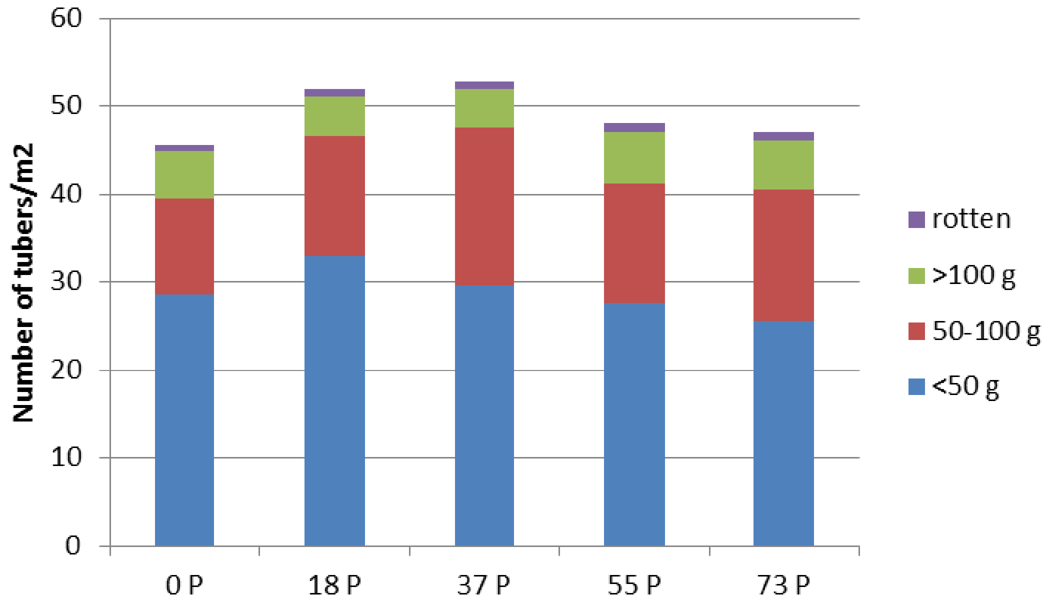


Figure 3.18. Number of tubers in the P-demo in Pangalengan during the dry season of 2015.

Yield data are shown in Table 3.28 and Figure 3.19. There is a clear effect of phosphate fertilization on yield, the highest P_2O_5 level (167 kg/ha) resulted in the highest total yield, which was significantly higher than yields obtained with 85 kg P_2O_5/ha and lower. Yields in this demo were overall very low, with a maximum of 23.8 ton healthy tubers/ha. This low yield level is due to the dry weather conditions in Pangalengan prevailing during the growing season in May and June, while irrigation was limited.

Table 3.28. Yield per class (ton/ha) and total yield (ton/ha) in the P-demo in Pangalengan during the dry season of 2015.

	Yield per class						
	Healthy tubers			Rotten	Total healthy yield	Total healthy	Total yield
Treatment	<50 g	50-100 g	>100 g	tubers	>50 g	yield	(incl. rotten)
0 P	8.2	6.9	5.4	0.3	12.3	20.5	20.8
18 P	8.5	8.5	4.6	0.4	13.1	21.6	22.0
37 P	7.4	10.3	4.7	0.5	15.0	22.4	22.8
55 P	8.7	8.1	6.3	0.5	14.4	23.1	23.5
73 P	8.2	9.6	6.0	0.4	15.6	23.8	24.2
F.Prob	n.s.	<0.05	<0.10	n.s.	<0.05	<0.001	<0.001
LDS 5%	-	2.1	1.3	-	2.3	1.0	1.1

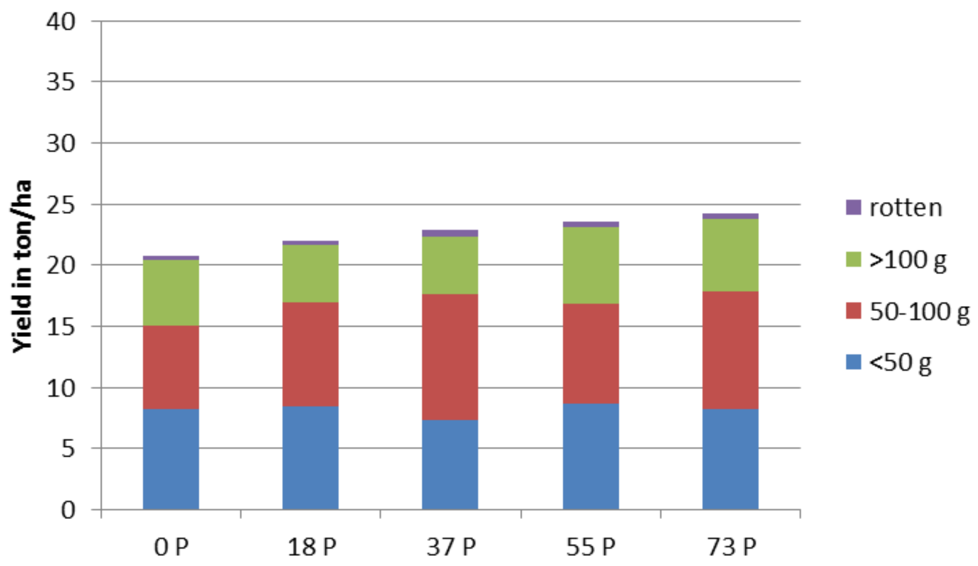


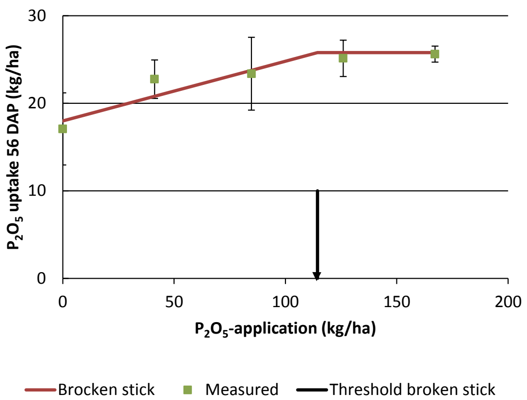
Figure 3.19. Yield in the P-demo in Pangalengan during the dry season of 2015.

Table 3.29 shows the number of harvested plants and the dry matter and P_2O_5 content of crop parts at 56 days after planting and harvest. There were no clear differences between phosphate fertilization levels in dry matter and P_2O_5 content.

Table 3.29. Number (#) of harvested plants per m^2, dry matter and phosphate content of aboveground biomass and tubers in the P-demo in Pangalengan during the dry season of 2015.

		Dry matter %			P_2O_5-content (% in dry matter)		
		56 days after planting		Harvest	56 days after planting		Harvest
Treatment	# of plants per m^2	Stems and leaves	Tubers	Tubers	Stems and leaves	Tubers	Tubers
0 P	4.4	10.3	14.4	19.0	0.27	0.23	0.20
18 P	4.4	10.5	16.7	19.0	0.27	0.23	0.21
37 P	4.4	10.2	13.9	18.1	0.27	0.23	0.21
55 P	4.4	10.4	15.8	18.7	0.27	0.23	0.20
73 P	4.4	10.3	16.1	19.1	0.28	0.24	0.20
F.Prob	n.s.	n.s.	n.s.	n.s.	n.s.	<0.10	n.s.
LDS 5%	-	-	-	-	-	0.01	-

Figure 3.20 shows that the increase in P_2O_5 uptake above an application of 41 kg P_2O_5/ha is stagnating. The optimal P_2O_5-application was estimated at 114 kg P_2O_5/ha using the broken stick method and 165 kg P_2O_5/ha using the quadratic plateau method. The broken stick method is a conservative estimate of the optimal P_2O_5-application whereas the quadratic plateau method has the tendency to overestimate the optimal P_2O_5-application as this curve slowly approaches the break-even point.



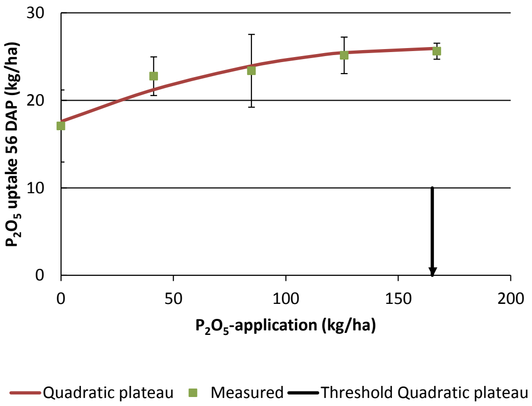


Figure 3.20. *The estimated optimal P_2O_5-application for the broken stick method (left, R^2 = 48.6%) and the quadratic plateau method (right, R^2 = 50.8%), Pangalengan, dry season 2015. Arrow indicates the break-even point, that is where an extra application of 1 kg P_2O_5/ha does not result in more P_2O_5 uptake. Vertical bars at measuring data indicate standard error of mean.*

Figure 3.21. *Overview of the P-demo (right) and evaluation of the yield (left).*

3.4.2. Garut

Plant heights during the growing season are shown in Table 3.30 and Figure 3.22. Differences between P_2O_5-levels were small.

Table 3.30. *Plant heights at different moments in the P-demo in Garut during the dry season of 2015.*

	Days after planting									
Treatment	20	27	34	42	48	53	62	69	76	83
0 P	8.9	17.5	27.0	42.4	47.8	53.1	52.6	52.3	56.8	54.0
18 P	6.9	20.5	28.1	46.7	49.9	60.4	55.4	57.6	60.4	56.5
37 P	7.7	22.8	34.4	44.3	49.4	51.9	54.7	56.1	57.4	55.8
55 P	10.8	23.1	31.0	49.3	54.5	56.3	55.3	55.0	59.8	54.0
73 P	7.3	19.7	27.7	42.0	50.7	57.0	57.9	60.4	62.3	56.0
F.Prob	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

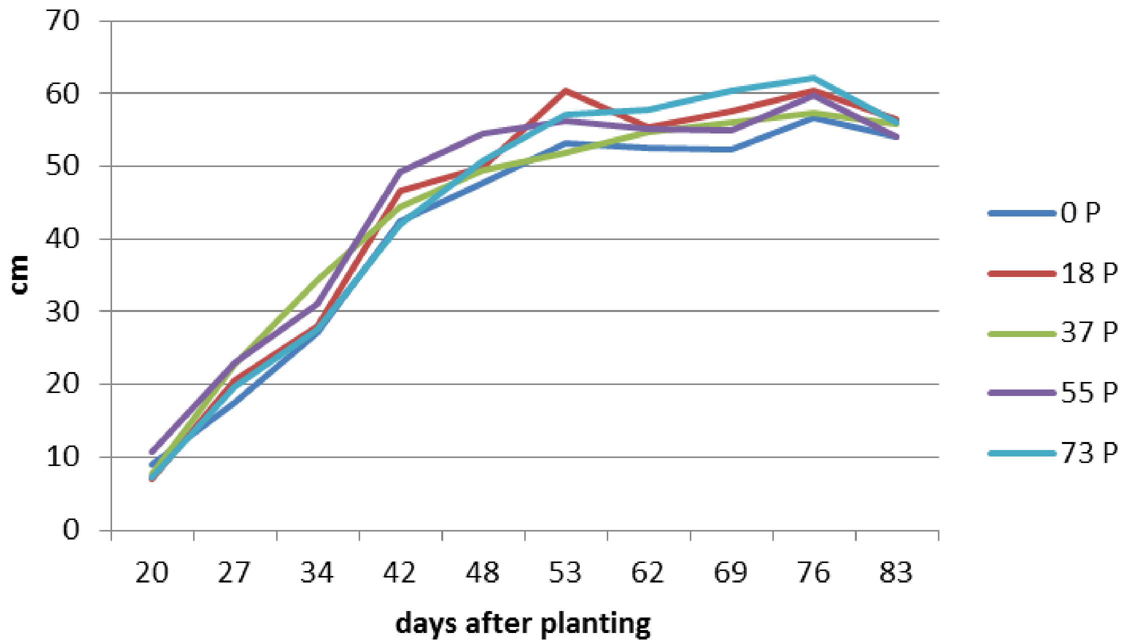


Figure 3.22. Plant heights in the P-demo in Garut during the dry season of 2015.

Numbers of tubers per class are shown in Table 3.31 and Figure 3.23. There were significant differences in the number of tubers among fertilizer treatments. The two highest phosphate levels showed significant more tubers than the lower phosphate levels.

Table 3.31. Number of harvested tubers (#/m^2) in the P-demo in Garut during the dry season of 2015.

	# of tubers per class					
	Healthy tubers					
Treatment	<50 g	50-100 g	>100 g	Rotten tubers	Total # of healthy tubers	Total # of tuber (incl. rotten)
0 P	10.0	10.5	12.7	1.2	33.3	34.4
18 P	9.1	11.6	13.7	0.1	34.4	34.6
37 P	8.3	9.9	17.0	1.0	35.1	36.1
55 P	12.7	12.5	15.9	0.7	41.1	41.9
73 P	11.8	12.7	15.1	0.9	39.6	40.5
F.Prob	<0.10	n.s.	<0.10	n.s.	<0.01	<0.01
LDS 5%	3.5	-	3.3	-	3.7	3.8

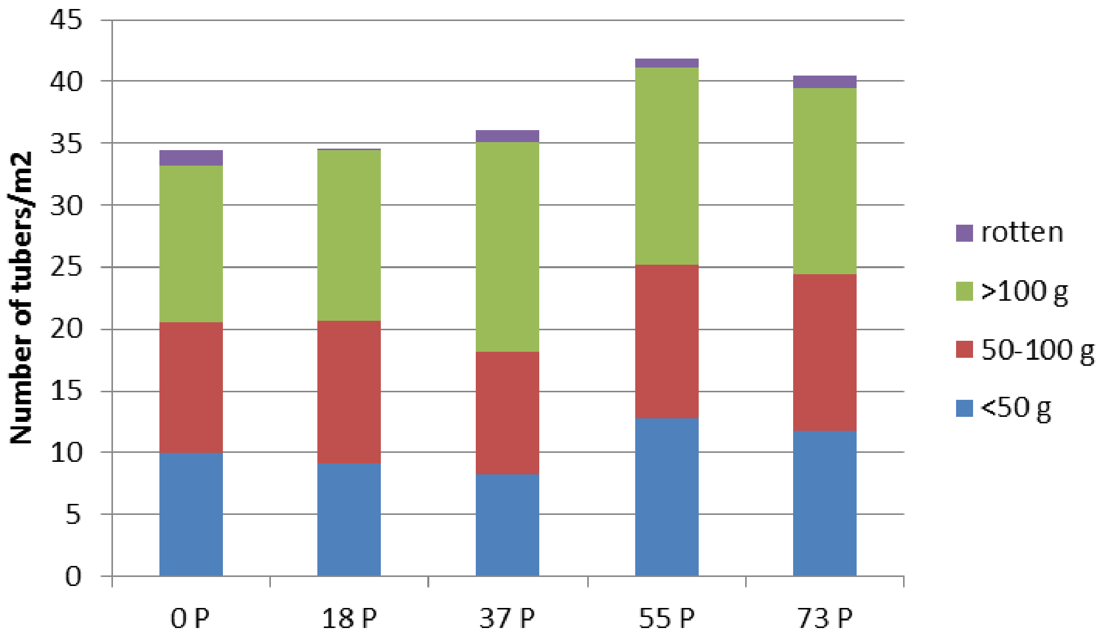


Figure 3.23. Number of tubers in the P-demo in Garut during the dry season of 2015.

Yield data are presented in Table 3.32 and Figure 3.24. The two highest phosphate levels had a significant higher yield than the lower phosphate levels. The yields in this demo were very high, up to 39 ton healthy tubers/ha.

Table 3.32. Yield per class (ton/ha) and total yield (ton/ha) in the P-demo in Garut during the dry season of 2015.

	Yield per class						
	Healthy tubers			Rotten	Total healthy yield	Total healthy	Total yield
Treatments	<50 g	50-100 g	>100 g	tubers	>50 g	yield	(incl. rotten)
0 P	3.3	7.6	17.6	0.6	25.2	28.5	29.1
18 P	2.7	9.3	20.6	0.1	29.9	32.6	32.7
37 P	2.6	7.2	25.1	0.7	32.3	34.9	35.6
55 P	4.1	9.8	24.7	0.6	34.5	38.6	39.2
73 P	3.7	10.2	23.7	0.6	33.9	37.6	38.2
F.Prob	<0.10	n.s.	<0.05	n.s.	<0.001	<0.001	<0.001
LDS 5%	1.2	-	4.5	-	3.2	2.4	2.6

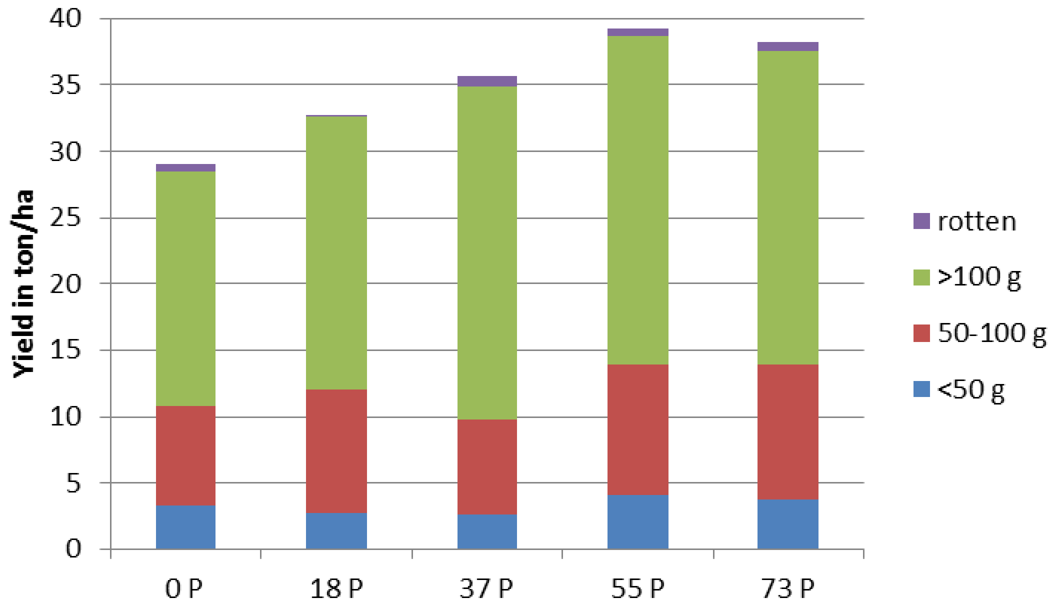


Figure 3.24. Yield in the P-demo in Garut during the dry season of 2015.

Table 3.33 presents the number of harvested plants and the dry matter and P_2O_5 content of crop parts at 56 days after planting and harvest. There were no clear differences between phosphate fertilization levels in dry matter and P_2O_5 content.

Table 3.33. Number of harvested plants (#/m^2), dry matter and phosphate content of aboveground biomass and tubers in P-demo in Garut during the dry season of 2015.

		Dry matter %			P_2O_5-content (% in dry matter)		
	# of plants	56 days after planting		Harvest	56 days after planting		Harvest
Treatment	per m^2	Stems and leaves	Tubers	Tubers	Stems and leaves	Tubers	Tubers
0 P	4.4	10.3	14.4	17.3	0.2	0.2	0.2
18 P	4.3	10.0	14.1	17.3	0.2	0.2	0.2
37 P	4.4	10.3	14.8	16.7	0.3	0.2	0.2
55 P	4.4	9.5	14.6	17.4	0.2	0.2	0.2
73 P	4.4	9.6	14.7	16.9	0.3	0.3	0.2
F.Prob	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

Figure 3.25 shows that the increase in P_2O_5 uptake above an application of 41 kg P_2O_5/ha is stagnating. The optimal P_2O_5-application was estimated at 104 kg P_2O_5/ha using the broken stick method and 126 kg P_2O_5/ha using the quadratic plateau method. The broken stick method is a conservative estimate of the optimal P_2O_5-application whereas the quadratic plateau method has the tendency to overestimate the optimal P_2O_5-application as this curve slowly approaches the break-even point.

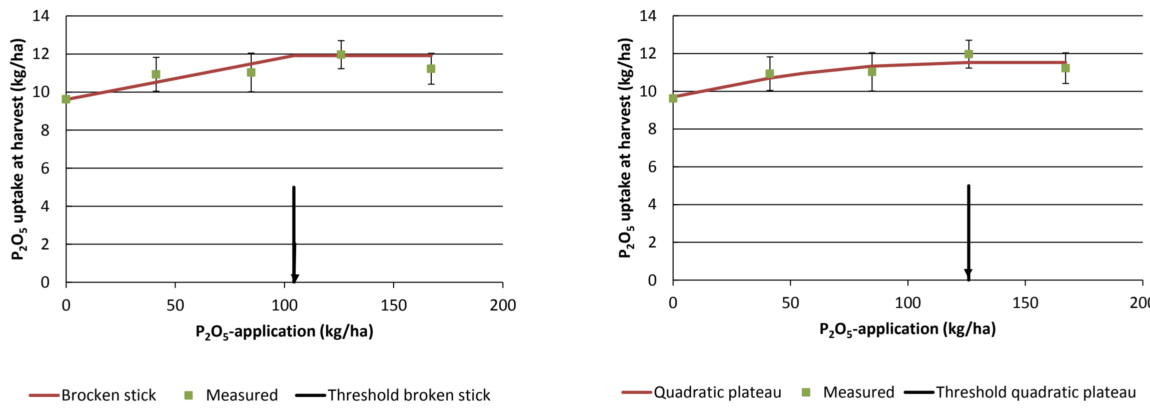


Figure 3.25. The estimated optimal P_2O_5-application for the broken stick method (left, R^2 = 78.4%) and the quadratic plateau method (right, R^2 =41.2%), Garut, dry season 2015. Arrow indicates the break-even point, that is where an extra application of 1 kg P_2O_5/ha does not result in more P_2O_5 uptake. Vertical bars at measuring data indicate standard error of mean.

4. Discussion and conclusions

4.1. N available from manure

Table 4.1 shows the applied amount of nitrogen at each location based on the nitrogen in both the applied manure and in inorganic N fertilizer. The actual availability of nitrogen from manure for the potato crop was 52 to 55% of the total amount applied (Table 3.1). These estimates however, do not account for the potential large part of uric acid (10 to 70%) in the chicken manure (Velthof*, et al.* 1999). Uric acid N is not organically bound but analysed as such because the analysis N-Kjeldhal includes uric acid N as being organically bound N. Uric acid N is rapidly transformed into ammonium under warm and moist condition and subsequently transformed into ammonia emissions. It is very well possible that the uric acid N was transformed into ammonia before the potato crop could benefit from it. It would have been better to include a treatment without manure and chemical N fertilizers, a true zero, as then the N-uptake from the manure and yield could have been identified.

4.2. N-demos in wet season 2014/2015

4.2.1. Soils and manure

The soil analysis of the N demos in the wet season 2014/2015 showed a low soil N with little differences between the fields in Pangalengan and Garut (Table 2.3), and similar as in the N-demos during the dry season of 2014, 0.54% (Van den Brink*, et al.* 2015a). The soil phosphate and potassium content in Garut were both somewhat higher than in Pangalengan.
The N content of the applied organic manure in Pangalengan was twice as high as in Garut, i.e. 1.41% in Garut and 2.87% in Pangalengan (Table 2.2). Chicken manure is known the have a large variation in N-content as this depends on the fodder fed to the chickens and on the stable system the chickens are kept (Van Dijk*, et al.* 2004). When in the stable system the manure is dried fast the manure most likely contains more uric acid N than when the manure stays moist for a longer period of time, facilitating the transformation to ammonium and ammonia evaporation.
The relatively high N-content of the organic manure in Pangalengan resulted in much higher N levels than planned. In all treatments high amounts of available phosphate and potash were applied, and we do not expect that phosphate and potassium have limited production in the demos.

4.2.2. N-treatment effects on growth

In Pangalengan, no differences between N-treatments were observed on plant height and percentage of soil cover, which may be attributed to the overall high N input in all treatments associated with the high N manure application. In general, yields in Pangalengan were low, i.e. around 21 ton healthy tubers/ha, without significant differences between N-levels. Many plants showed symptoms of wilting during the growing season, probably because of bacterial diseases. According to farmers and agronomists in Indonesia bacterial diseases are not only seed born, but also soil born. Percentage of diseased plants at harvest was on average 38%, which is extremely high. Also the percentage of rotten tubers at harvest was very high (on average 26%). Because of these high percentages of wilted plants and rotten tubers, the N-demo in Pangalengan gave no useful information on the crop-N response.

In Garut there were no significant differences between the treatments in N content of the leaves, stem, roots and tubers (Table 3.13). In dry matter content there were some differences among treatments, but not always significant. The lower N-application tended to have a higher dry matter content, which may be expected (O' Beirne and Cassidy 1990).

The N-demo in Garut during the wet season 2014/2015 showed that an amount between 107 to 170 kg/ha N from chemical fertilizers (Figure 3.9; i.e. 223 to 286 kg N/ha including 116 kg N/ha from chicken manure, Table 3.1) is sufficient to obtain a high yield. Yield reductions happen when 60 kg N/ha of chemical fertilizers or less is available, while increasing the amount of available N beyond 107 kg/ha hardly resulted in higher yields. The estimated available N from manure is substantial compared to the chemical N application, 116 kg N/ha when 107 to 170 kg N/h with chemical fertilizers is found sufficient. To optimize fertilization the N-content of the applied organic manure needs to be known to farmers.

The results of the N-demo in the dry season of 2014 showed that 100 kg N/ha from chemical fertilizers (130 to 175 kg N/ha including 50% of N available from manure application) was sufficient for obtaining maximum yield (Van den Brink*, et al.* 2015a). In the rainy season the optimum N-level is slightly higher, maybe because of higher N losses in the wet season.

In Garut, plant height and soil cover differed among the N levels, biomass development of 0 N lagged significantly behind, while also crop development of 60 N was slower than the other N levels (Figure 3.4 and Figure 3.5). Treatments 0 N and 60 N produced respectively 43 and 19% less yield than treatment 120 N (

Table 3.11). The average yield level in Garut was much higher than in Pangalengan (32 *vs*.21 ton healthy tubers/ha).

4.2.3. N-surplus and apparent nitrogen recovery

The N-balance, calculated as the total amount of nitrogen applied minus the N removed with the harvested tubers, shows that the surplus varied between 170 kg N/ha in Garut (no chemical fertilizer) to 617 kg/ha in Pangalengan when 240 kg N/ha chemical fertilizers was applied on top of the 431 kg N/ha applied with chicken manure (Table 4.1).

The amount of available N in Garut ranged from 116 to 356 kg/ha, while in Pangalengan it was substantially higher ranging from 235 to 475 kg/ha (Table 3.1).

Table 4.1. Nitrogen (N) applied (from chemical and manure applications), N removed with finished product and N surplus in the N-demos (kg N/ha) in Pangalengan and Garut during the wet season 2014/ 2015.

		Pangalengan			Garut		
Treatment	Chemical fertilizer	Manure	Removed	Surplus	Manure	Removed	Surplus
0 N	0	431	50	381	212	41	170
60 N	60	431	40	451	212	62	210
120 N	120	431	53	498	212	74	258
180 N	180	431	50	560	212	73	318
240 N	240	431	53	617	212	73	379

The Apparent Nitrogen Recovery (ANR, %) of the chemical fertilizer was calculated at 60 days after planting and at harvest as the difference of the N yield of the fertilized crop and the non-fertilized control crop, expressed as a percentage of the total N input from the fertilizer (Schröder*, et al.* 2007). Table 4.2 shows that ANR ranges from 12% to 58%. ANR 60 days after planting is significant higher at treatment 60 N than the other treatments whereas at harvest there are no differences in ANR between treatments. The low ANR's at harvest agree with the high N-surplus shown in Table 4.1. Because yields of treatment 60 N are suboptimal, an ANR of approximately 30% seems to be the maximum achievable ANR in the potato cultivation of Granola in Garut.

Table 4.2 The Apparent Nitrogen Recovery (ANR, %) 60 days after planting and at harvest in Garut during the wet season 2014/15 calculated as the uptake between fertilized and not fertilized treatments divided by the applied amount chemical N fertilizer.

		ANR	
Treatment	Chemical N (kg/ha)	60 days after planting	Harvest
0 N	0	-	-
60 N	60	58	34
120 N	120	36	32
180 N	180	12	27
240 N	240	21	22

F.Prob.	0.021	n.s.
LSD 5%	25.4	-

4.2.4. Final remarks

In the nitrogen fertilization demos, due to the high percentages of wilted plants and rotten tubers, the N-demo in Pangalengan gave no useful information on the crop-N response. The N-demo in Garut during the wet season 2014/2015 showed that an amount of 107 to 170 kg/ha available N from chemical fertilizers plus 15 tons/ha manure is sufficient to obtain a high tuber yield. This demo suggests that for potato cultivation with cv. Granola, the available N should be slightly more in the wet season compared to the potato cultivation in the dry season as indicated in the previous demos conducted in the dry season 2014 in which the available N was sufficient between 100 kg N/ha from chemical fertilizers plus 15 tons/ha manure for obtaining maximum yields.

4.3. NP-demo in dry season 2015

4.3.1. Soils and manure

The soil analysis of the NP demo fields both in Garut and Pangalengan indicated a low soil N content. The soil in Pangalengan contained more phosphate than in Garut

Table 2.6).

The N content of the applied organic manure in Garut and Pangalengan was not much different, 1.37% in Garut and 1.57% in Pangalengan (Table 2.5). Table 4.1 shows the amount of nitrogen (theoretically) available at each location based on the nitrogen in both the applied manure and in inorganic N fertilizer. The modelled available nitrogen from manure is ≈ 53% of the total manure N (Table 3.1) although emissions of ammonia may have reduced this amount (section 4.1). The nitrogen content of the applied organic manure was higher than expected and resulted in higher available N levels than planned: N availability at Pangalengan ranged from 202 (82 in manure and 120 in chemical fertilizer) to 322 (82 in manure and 240 in chemical fertilizer) kg N/ha and from 195 (75 in manure and 120 in chemical fertilizer) to 315 (75 in manure and 240 in chemical fertilizer) kg/ha in Garut in the treatments, assuming no emissions of ammonia from the manure.

In all treatments high amounts of potash were available, 200 kg K_2O/ha from chemical fertilizers and 174 kg K_2O/ha from organic manure in Garut and 192 kg K_2O/ha from organic manure in Pangalengan. Therefore, it is expected that potash did not limit production in both Pangalengan and Garut.

4.3.2. NP-treatment effects on growth

In both regions, plant heights were not different across fertilization treatments, but Atlantic plants were generally higher than Granola plants.

The plant analysis showed at both demos differences in dry matter content between Atlantic and Granola (Table 3.17 and Table 3.23). Atlantic is a variety with a high dry matter content, therefore it is mainly grown for the processing industry. Differences between fertilizer treatments on dry matter content and nitrogen content were small and not significant.

Yield levels in the NP-demo were quite high, Granola yielded on average 34.7 ton healthy tubers/ha in Pangalengan and on average 29.1 ton/ha in Garut. Atlantic gave yields of 27.7 ton healthy tubers/ha in Pangalengan and 39.1 ton healthy tubers/ha in Garut. The reason for the interaction between varieties and regions is possible caused by a difference in seed quality. There was a clear difference in percentage of rotten tubers between varieties and regions. In Garut both varieties had the same percentage rotten tubers, i.e. Atlantic 5.7% and Granola 5.6%, while in Pangalengan there was a clear difference, i.e. Atlantic 12.1% and Granola 5.6%.

There was no effect of the applied P fertilizer (0 *vs.* 250 kg P_2O_5/ha) on potato yields in both Pangalengan and Garut. Probably sufficient phosphate was supplied through the phosphate contained in the manure.

For both varieties no significant yield differences were observed among the four N levels. In both regions and in both varieties the lowest two N levels (120 kg N/ha and 160 kg N/ha from chemical fertilizer and 10 ton organic manure) resulted in the same yield as the higher N levels. In the dry season of 2014, N-demos showed that 100 kg N/ha together with 10 ton organic manure (i.e. in total 130 to 175 kg available N/ha for Garut and Pangalengan, respectively) resulted in maximum yields (Van den Brink*, et al.* 2015a). Again, less N from chicken manure may have been available for crop uptake because of N emission (section 4.1). The 100 kg N/ha from chemical fertilizers, being sufficient to attain maximum yields, agrees with findings of the N-demos of the wet season 2014/15 (section 3.1). These findings show promising perspectives for reducing nutrient inputs and associated costs in potato production while maintaining potato yields and potato quality in Pangalengan and Garut.

4.3.3. N-surplus and P-surplus

The surplus of N was calculated as the input of manure and chemical fertilizer minus the amount of N removed with the harvested product and ranged from 157 kg N/ha to almost 300 kg N/ha (Table *4.3*). The N removed with the harvested product was the same for all treatments although in Pangalengan Granola removed more N than Atlantic and in Garut Atlantic removed more N than Granola. The lack of a treatment effect on N-removal is in agreement with the results for the optimal N-application rate of 107 to 170 kg N/ha (Figure 3.9).

Table 4.3. *Nitrogen applied (from chemical fertilizer and manure applications), N removed with harvested product and N surplus in the NP-demos (kg/ha) in Pangalengan and Garut during the dry season of 2015.*

			Pangalengan			Garut		
Treatment	Variety	Chemical fertilizer	Manure	Removed	Surplus	Manure	Removed	Surplus
120N/250P	Granola	120	157	120	157	137	86	171
160N/250P		160	157	117	200	137	69	228
200N/250P		200	157	139	218	137	81	256
240N/250P		240	157	135	262	137	79	298
Average				127			82	
120N/250P	Atlantic	120	157	114	163	137	117	140

160N/250P	160	157	130	187	137	114	183
200N/250P	200	157	116	241	137	128	209
240N/250P	240	157	103	294	137	117	260
Average			113			126	
F.Prob.			0.037			<0.001	
LSF 5%			13.2			14.8	

Surplus of phosphate was calculated as the input of manure and chemical fertilizer minus the amount of phosphate removed with the harvested product and ranged from 315 kg P_2O_5/ha to almost 625 kg P_2O_5/ha (

Table *4.4*). Treatment had no effect on phosphate removal.

Table 4.4. Phosphate (P_2O_5) applied (from chemical fertilizer and manure applications), P_2O_5 removed with finished product and P_2O_5 surplus in the NP-demos (kg/ha) in Pangalengan and Garut during the dry season of 2015.

			Pangalengan			Garut		
Treatment	Variety	Chemical fertilizer	Manure	Removed	Surplus	Manure	Removed	Surplus
0 P	Granola	0	350	35	315	417	22	395
	Atlantic		350	32	318	417	38	379
250 P	Granola	250	350	34	566	417	26	641
	Atlantic		350	29	571	417	42	625

4.3.4. Final remarks

Because of the relatively high available N no differences in tuber yield were observed between N treatments in both regions. In both varieties the lowest two N levels (120 kg N/ha and 160 kg N/ha from chemical fertilizers and 10 ton organic manure) resulted in the same yield as the higher N levels. This finding confirms the results of the N fertilization demo of wet season 2014/2015 (section 4.2) and the N fertilization demo conducted in the previous dry season 2014 which indicated that 100 kg N/ha together with 10 ton organic manure/ha (i.e. in total 200 kg available N/ha) was sufficient to obtain maximum yields. Hence, both demos in the dry seasons of 2014 and 2015 suggest that 100 to 170 kg available N/ha from chemical fertilizers probably is sufficient to attain maximum yields. In terms of P_2O_5, there was no effect of the applied P_2O_5 fertilizer (0 *vs.* 250 kg P_2O_5/ha) on potato yields in both Garut and Pangalengan as probably sufficient phosphate was supplied through the phosphate contained in the manure.

4.4. P-demo in dry season 2015

4.4.1. Soils and manure

The soil analysis of the P-demo fields indicated at a low soil N content in both Pangalengan and Garut. The phosphate content of both demo fields in Garut and Pangalengan hardly differed. Soil potash content was very low in Pangalengan (Table 2.9).

Phosphorus exists in soils as non-labile P, labile P and soil solution P. The soil soluble P concentration is usually very low and easily exhausted. But because roots grow they encounter “fresh” soil solution with P. When the P concentration is diminished by P removal it is replenished by labile P which in turn is replenished much more slowly by non-labile P. To evaluate the available P status of soils by chemical tests it is needed to consider the relationship among quantity, intensity and diffusion, and factors influencing these three components of P supply to plants. The buffering capacity of acid and neutral soils is a function of the amounts of crystallinity of hydrated oxides of Fe and Al (Kamprath and Watson 1980). Soils in the upland of West Java have parent material from volcanic ash, typically high silicate clay mineral contents and show large sorption capacity for P (Hartono*, et al.* 2005). This may contribute to the difficulty in determination of the optimal phosphorus fertilization level. The measured Olsen P status of the soils was high, 359 mg P_2O_5/kg in Pangalengan and 444 mg P_2O_5/kg in Garut, as normal plant critical values range from 23 to 50 mg P_2O_5/kg (Syers*, et al.* 2008). Values found in this study are much higher and effects of P-treatments on yield may be small.

There were no large differences in phosphate content of the used organic manure in Pangalengan and Garut, i.e. 4.17% in Garut and 3.50% in Pangalengan (Table 2.8). The larger part of phosphate in chicken manure is in the mineral form, 80% (Ehlert*, et al.* 2004) and solves easily in water. Only 20% of the phosphate is in the organic form. Table 4.5 shows the total amount of phosphate at each location based on the phosphate of both the applied manure and inorganic P_2O_5 fertilizer. The actual availability of phosphate from this chicken manure for the potato crop is not exactly known. It is estimated that for Dutch conditions about 80% of the phosphates become available to the plant within 8 months compared to the same application of triple superphosphate (Ehlert*, et al.* 2004). Considering the temperature difference between the Netherlands and Indonesia, it is likely that 70 to 80% of the manure phosphate becomes soluble and therefore available for crop uptake. But, volcanic soils may have a large sorption capacity for phosphate, depending on the amount of crystallinity of hydrated oxides of Fe and Al (Kamprath and Watson 1980). pH has also influence on P-availability.

In all treatments enough nitrogen was available, 180 kg N/ha from urea and 75 kg available N/ha from organic manure in Garut and 82 kg available N/ha from organic manure in Pangalengan (Table 3.1). Considering that approximately 107 to 170 kg N/ha from chemical fertilizers is required for maximum yield (section 4.2) available N was not limiting yield.

In all treatments also high amounts of potash were available, 200 kg K_2O/ha from chemical fertilizers (applied one day before planting) and 174 kg K_2O/ha from organic manure in Garut and 192 kg K_2O/ha from organic manure in Pangalengan. Therefore, it is unlikely that K has limited yield in the P demos.

4.4.2. P-treatment effects on growth

In both regions, no differences between phosphate fertilization treatments were observed in plant height. Also differences between phosphate fertilizer treatments in dry matter content and phosphate content were small and not significant.

Average yield level in Garut was much higher than in Pangalengan (34.4 *vs* 22.3 ton healthy tubers/ha), which is related to the shortage of irrigation water in Pangalengan. In both regions were significant yield differences between phosphate levels (Table 3.28 and Table 3.32). In Garut, yields increased up to the treatment 37 P, that is 85 kg P_2O_5/ha. The highest phosphate level yielded 32% more than the lowest level. In Pangalengan, the highest phosphate level yielded 16% more than the lowest level (Table 3.28). The phosphate removed with the harvested product showed similar response to the treatments, the 0 P treatment removed less phosphate than some of the fertilized treatments.

The P-demos in Pangalengan and Garut during the dry season 2015 showed that an amount of 104 to 165 kg P_2O_5/ha from chemical fertilizers is sufficient to obtain a high yield (Figure 3.20 and Figure 3.25). When including phosphate available from manure applications, this becomes, 359 to 410 kg P_2O_5/ha in Pangalengan and 395 to 417 kg P_2O_5/ha in Garut.

Although the majority of the phosphate in potato production is applied with organic manure, application of small amounts of phosphate through chemical fertilizer is essential to get high yields in Pangalengan and Garut. This yield response to small amounts of chemical P fertilizers maybe related to the application method as the phosphate fertilizer was applied one day before planting close to the seed tubers and this is very beneficial to the plants (Smit*, et al.* 2010), while (phosphate from) organic manure was applied and mixed over the whole planting beds. In addition, especially in Pangalengan, the relatively low soil pH could have limited the availability of phosphate from manure.

4.4.3. P-surplus and apparent phosphate recovery

The surplus of P_2O_5 was calculated as the input of manure and chemical fertilizer minus the amount of P_2O_5 removed with the harvest product and ranged from 333 kg P_2O_5 /ha to more than 500 kg P_2O_5 /ha (Table 4.5). The P_2O_5 removed with the harvested product was lowest for the unfertilized treatment in both locations and showed the lowers surplus.

Table 4.5. Phosphate (P_2O_5) applied (from manure and chemical fertilizer applications), P_2O_5 removed with finished product and P_2O_5 surplus in the P-demos (kg P_2O_5/ha) in Pangalengan and Garut during the dry season of 2015.

		Pangalengan			Garut		
Treatment	Chemical fertilizer	Manure	Removed	Surplus	Manure	Removed	Surplus
0 P	0	350	17.1	333	417	9.6	340
18 P	41	350	21.2	370	417	10.4	380
37 P	85	350	18.1	417	417	11.0	424
55 P	126	350	21.1	455	417	12.0	464
73 P	167	350	21.5	496	417	11.2	506
F.Prob.			<0.001			0.14	
LSD 5%			1.12			1.18	

Table 4.6 The Apparent Phosphate Recovery (APR, %) 56 days after planting and at harvest in Pangalengan and Garut during the dry season 2015 calculated as the uptake between fertilized and not fertilized treatments divided by the applied amount of chemical P_2O_5 fertilizer.

		APR			
		Pangalengan		Garut	
Treatment	Chemical P_2O_5 (kg/ha)	56 days after planting	Harvest	56 days after planting	Harvest
0 P	0	-	-	-	-
18 P	41	13	15	15	3
37 P	85	7	5	4	2
55 P	126	7	5	2	2
73 P	167	5	4	5	1
F.Prob		n.s.	<.001	0.022	n.s.
LSD 5%		-	3.90	6.81	-

The Apparent Phosphate Recovery (APR, %) of the chemical fertilizer was calculated at 56 days after planting and at harvest as the difference of the P_2O_5 yield of the fertilized crop and the non-fertilized control crop, expressed as a percentage of the total P_2O_5 input from the chemical fertilizer (Schröder, *et al.* 2007). Table 4.6 shows that APR ranges from 1 to 15%. In Garut, APR 56 days after planting is significantly higher at treatment 18 P (41 kg P_2O_5/ha) than the other treatments whereas at harvest there are no differences in APR between treatments. In Pangalengan the opposite is found, APR at harvest is significantly higher at treatment 18 P than the other treatments whereas at 56 days after planting there are no differences in APR between treatments. The low APR's at high application rates agree with the high P_2O_5-surplus shown in Table 4.5.

4.4.4. Final remarks

In the P-demos, in both regions, the effect of P rates was significant on the tuber yields. In Pangalengan, there is a clear effect of phosphate fertilization on yield, the highest P_2O_5 level (167 kg/ha) resulted in the highest total yield, which was significantly higher than yields obtained with 85 kg P_2O_5/ha and lower. In Garut, yields increased up to the treatment 37 P, 85 kg P_2O_5/ha. The highest phosphate level yielded 32% more than the lowest level. These demos suggest that although phosphate was available from the manure, the application of small amounts of phosphate through chemical fertilizer is essential to get high yields. The phosphate fertilizer application is essential one day before planting close to the seed tubers in order to optimize the uptake of P for the plants.

4.5. Conclusions

The fertilizer demonstrations were initiated to determine the optimum rate of nitrogen and phosphorus fertilizer on potatoes in Pangalengan and Garut, Indonesia.

The N-demonstrations show the response of potatoes (variety Granola) to several nitrogen rates (0, 60, 120, 180 and 24 kg N/ha) in the wet season 2014/2015 both Pangalengan and Garut. The findings of the N-demos were:

- No yield responses to N-fertilizer levels in Pangalengan due to the high percentages of wilted plants and rotten tubers.
- Tuber yields in Garut increased up to an application of 120 kg N/ha of chemical fertilizers and 15 ton/ha of chicken manure.
- The optimal N-application of chemical fertilizers for maximum yield of Granola in Garut was between 107 to 170 kg N/ha plus 15 tons/ha of chicken manure, depending on the method used to determine the optimal level, broken stick (linear plus plateau function) or quadratic plateau function.
- The N-surplus ranged from 170 to 379 kg N/ha in Garut. The N-surplus at an application rate of 120 kg N/ha was 210 kg N/ha.
- The apparent nitrogen recovery at an application of 120 kg N/ha in Garut was 32%.

The NP-demonstrations show the response of two potatoes varieties (Granola and Atlantic) to four levels of nitrogen fertilization (120, 160, 200 and 240 kg N/ha) and two levels of phosphate fertilization (0 and 250 kg P_2O_5/ha) in Pangalengan and Garut in the dry season 2015. The findings of the NP-demos were:

- Yield differences related to variety only and no yield responses to N-fertilizer levels were found. These findings agree with the optimal N-application of 107 to 170 kg N/ha from chemical fertilizers plus 15 tons/ha manure in the N-demo of the wet season 2014/2015 in Garut.
- There was no effect of the applied P fertilizer (0 vs. 250 kg P_2O_5/ha) on potato yields in both Pangalengan and Garut.
- N-surplus ranged from 157 to 294 kg N/ha in Pangalengan and from 140 to 298 kg N/ha in Garut and was slightly lower than the surplus in the N-demo of the wet season 2014/2015 in Garut.
- P_2O_5-surplus ranged from 315 to 571 kg P_2O_5/ha in Pangalengan and from 395 to 625 kg P_2O_5/ha in Garut.

The P-demonstrations show the response of potatoes (variety Granola) to various phosphorus rates (0, 41, 85, 126 and 167 P_2O_5/ha) in the dry season 2015 in Pangalengan and Garut. The findings of the P-demos were:

- The optimal N-application of chemical fertilizers for maximum yield of Granola in Garut was between 107 to 170 kg N/ha plus 15 tons/ha of chicken manure.
- The contribution of chicken manure to the N-supply of potato is not yet clear.
- To improve fertilization the N-content of the applied chicken manure and the N-use efficiency from chicken manure needs to be known.
- The low apparent nitrogen recovery as well as the large N-surplus show room for the development and implementation of techniques to increase N-use efficiency .
- Although the majority of the phosphate in potato production is applied with organic manure, application of small amounts of phosphate through chemical fertilizer is essential for high potato yields in Pangalengan and Garut.
- The optimal phosphate application of chemical fertilizers for maximum yield of Granola in Pangalengan and Garut was found to be between 114 to 165 and 104 to 126 kg P_2O_5/ha plus 10 tons/ha chicken manure, respectively.
- The low apparent phosphate recovery as well as the large P-surplus show room for the development and implementation of techniques to improve phosphate use efficiency.

From these demonstrations it is concluded that:

- The optimal N-application of chemical fertilizers for maximum yield of Granola in Garut was between 107 to 170 kg N/ha plus 15 tons/ha of chicken manure.
- The contribution of chicken manure to the N-supply of potato is not yet clear.
- To improve fertilization the N-content of the applied chicken manure and the N-use efficiency from chicken manure needs to be known.
- The low apparent nitrogen recovery as well as the large N-surplus show room for the development and implementation of techniques to increase N-use efficiency.
- Although the majority of the phosphate in potato production is applied with organic manure, application of small amounts of phosphate through chemical fertilizer is essential for high potato yields in Pangalengan and Garut.

- The optimal phosphate application of chemical fertilizers for maximum yield of Granola in Pangalengan and Garut was found to be between 114 to 165 and 104 to 126 kg P_2O_5/ha plus 350 and 417 kg P_2O_5/ha from manure, respectively.
- The low apparent phosphate recovery as well as the large P-surplus show room for the development and implementation of techniques to improve phosphate use efficiency.

These demonstrations show promising perspectives for reducing nutrient inputs and associated costs in potato production while maintaining potato yields and potato quality in Pangalengan and Garut.

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