



Optimization of sludge application to field crops as fertilizer substitute

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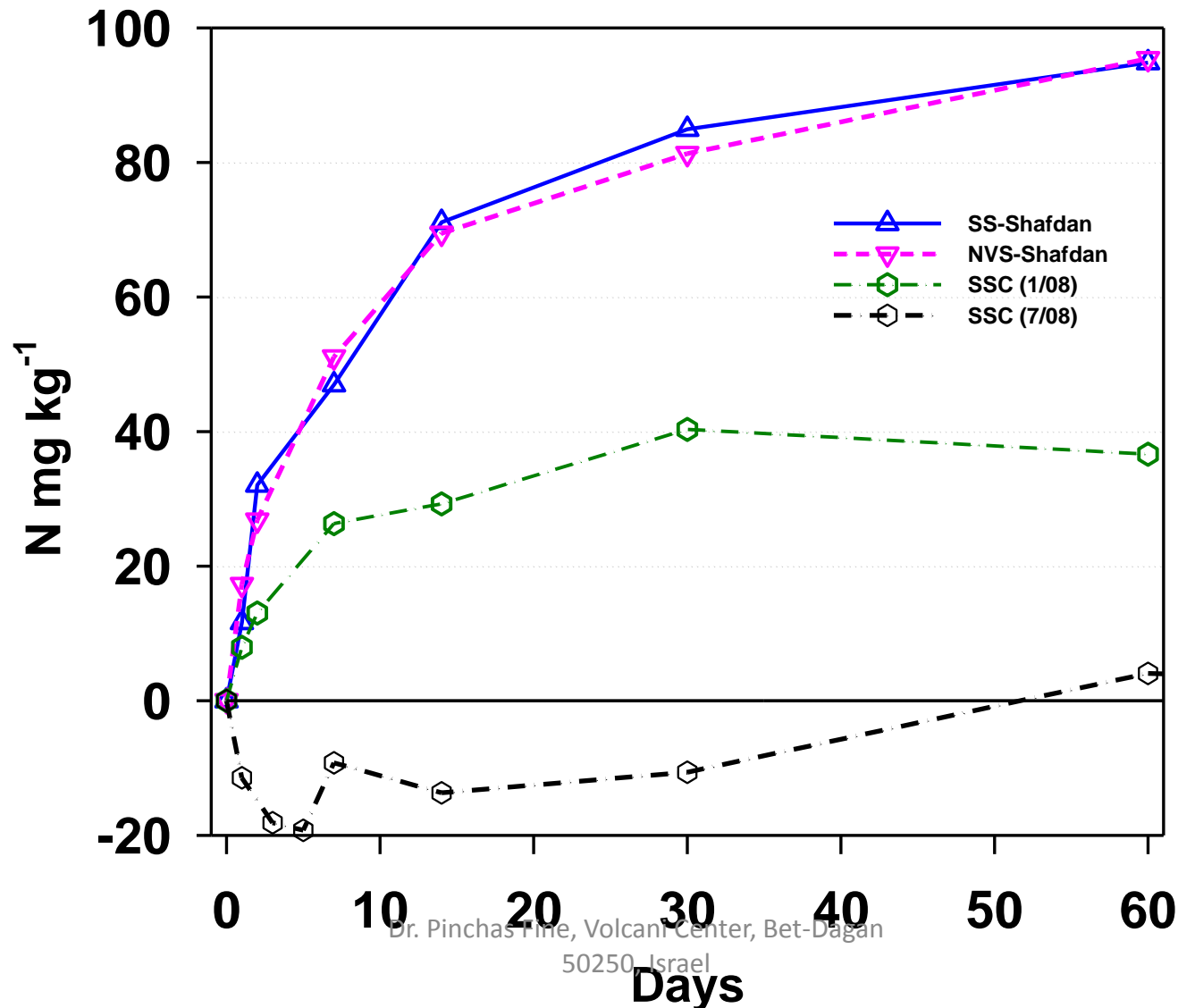
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Composition of manures applied at Revadim in 2011

Constituent in dry) (material	units	Shafdan sludge	Haifa sludge	Sludge compost	Municipal biosolids compost	N-Viro Shafdan
Dry material	% (fw)	22	20	59	60	71
Fly ash	%	23	24	53	64	88
C _{Organic}	- " -	37.7	38.7	22.2	19.8	8.0
N _{Total}	- " -	6.39	6.33	2.07	1.40	0.70
C _{Org} /N _{Org}	ratio	6.1	6.3	12.2	14.6	11.8
N-NH ₄	mg/kg	1,650	2,000	2,500	400	200
P _{Total}	%	1.3	2.2	1.3	0.32	0.36
K _{Total}	- " -	0.5	0.2	0.6	0.8	0.2
pH (1:5)		5.76	6.50	6.62	8.03	12.5
EC (1:5)	dS/m	5.9	7.8	6.6	1.4	2.6

Net mineralization of organic N

in sludge amended sand: an incubation study. Application rate equivalent to 500 kg N/ha; (incubation at optimal moisture content, 30°C)





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Field experiment plot design

96	95	94	93		92	91	90	89	F
81	82	83	84		85	86	87	88	
80	79	78	77		76	75	74	73	E
65	66	67	68		69	70	71	72	
64	63	62	61		60	59	58	57	D
49	50	51	52		53	54	55	56	
48	47	46	45		44	43	42	41	C
33	34	35	36		37	38	39	40	
32	31	30	29		28	27	26	25	B
17	18	19	20		21	22	23	24	
16	15	14	13		12	11	10	9	A
1	2	3	4		5	6	7	8	

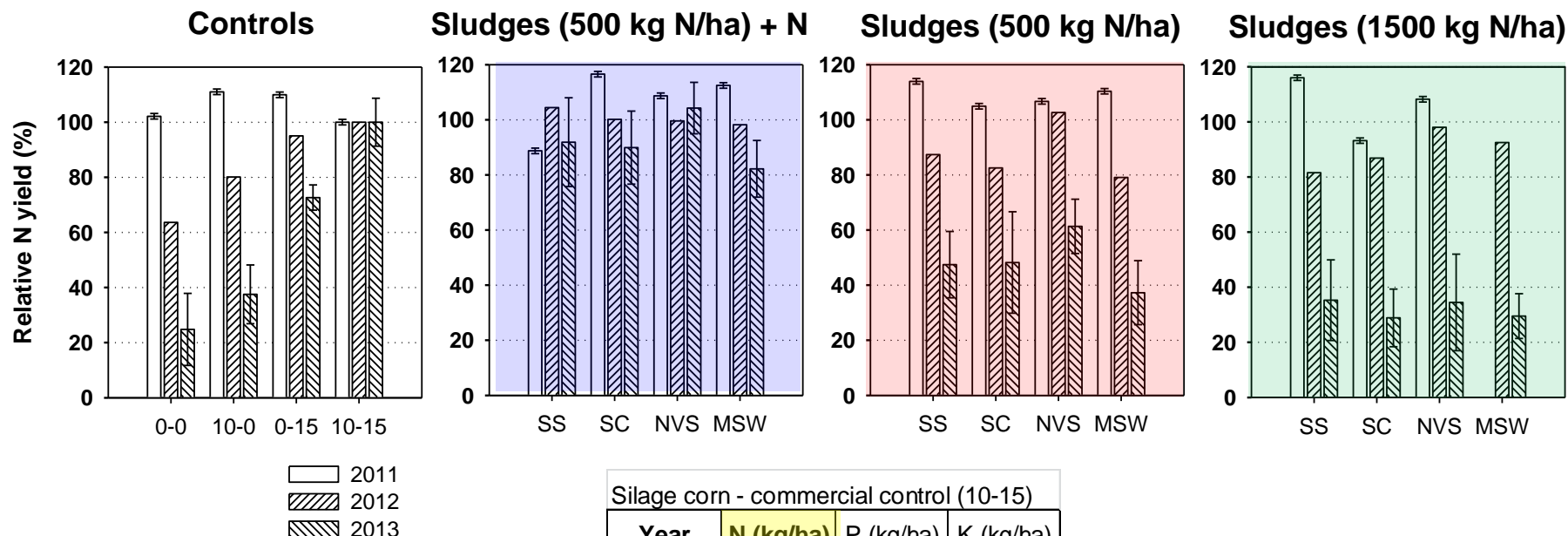
Treatments in the Revadim field study (4th year in 2014)

Treatments	Manure (m ³ /ha/y) and N (kg/ha) application			
	Manure	Base	Side	#
1 Cont 0-0	0	0	0	
2 Cont N-0	0	100	0	
3 Cont 0-N	0	0	150	3
4 Cont N-N	0	100	150	3
5 SS-500+N	5	0	150	3+
6 SC-500+N	6	0	150	3
7 NVS-500+N	10	0	150	3
8 MSW-500+N	8.5	0	150	3
9 SS-500	5	0	0	3
10 SC-500	6	0	0	3
11 NVS-500	10	0	0	3
12 MSW-500	8.5	0	0	3
13 SS-1500	15	0	0	3
14 SC-1500	18	0	0	1
15 NVS-1500	30	0	0	1
16 MSW-1500	25.5	0	0	1

Corn and wheat yields in the 3 years of the trial at Revadim

Treatments	2011 (corn)	2012 (corn)	2012/13 (wheat)	2013 (corn)	2013/14 (wheat)	Overall 2011-14	Net revenue
	% of the on-farm treatment (#4)						NIS/ha*1000
1 Cont0-0	100	69 d	77 c	41 f	55 cde	75 e	18 f
2 ContN-0	106	95 bc	97 abc	66 bcdef	74 cde	94 abcd	28 abcde
3 Cont0-N	100	84 c	81 bc	82 abcde	86 abcde	93 abcd	26 abcdef
4 ContN-N	100	100 ab	100 abc	100 ab	100 abcd	100 abc	29 abc
5 SS-500+N	86	110 a	110 a	88 abcd	104 abc	103 a	33 a
6 SC-500+N	94	99 ab	100 abc	89 abcd	115 a	103 a	27 abcdef
7 NVS-500+N	95	101 ab	87 abc	110 a	105 abc	102 ab	33 ab
8 MSW-500+N	102	92 bc	98 abc	92 abc	96 abcd	98 abcd	25 abcdef
9 SS-500	103	103 ab	94 abc	65 bcdef	107 ab	98 abcd	32 abc
10 SC-500	104	94 bc	103 abc	66 bcdef	91 abcd	95 abcd	23 cdef
11 NVS-500	98	95 bc	105 ab	79 abcde	99 abcd	93 abcd	28 abcd
12 MSW-500	105	87 c	99 abc	55 def	79 bcde	86 cde	19 ef
13 SS-1500	92	93 bc	101 abc	57 cdef	84 abcde	88 bcde	25 abcdef
14 SC-1500	104	94 bc	95 abc	42 f	77 bcde	88 bcde	19 def
15 NVS-1500	82	86 c	108 a	48 ef	69 de	86 de	24 abcdef
16 MSW-1500		86 c	102 abc	46 ef	89 abcd	90 abcd	
Treat#4(t/ha)		20.4	22.3	12.6	18.1	11.7	

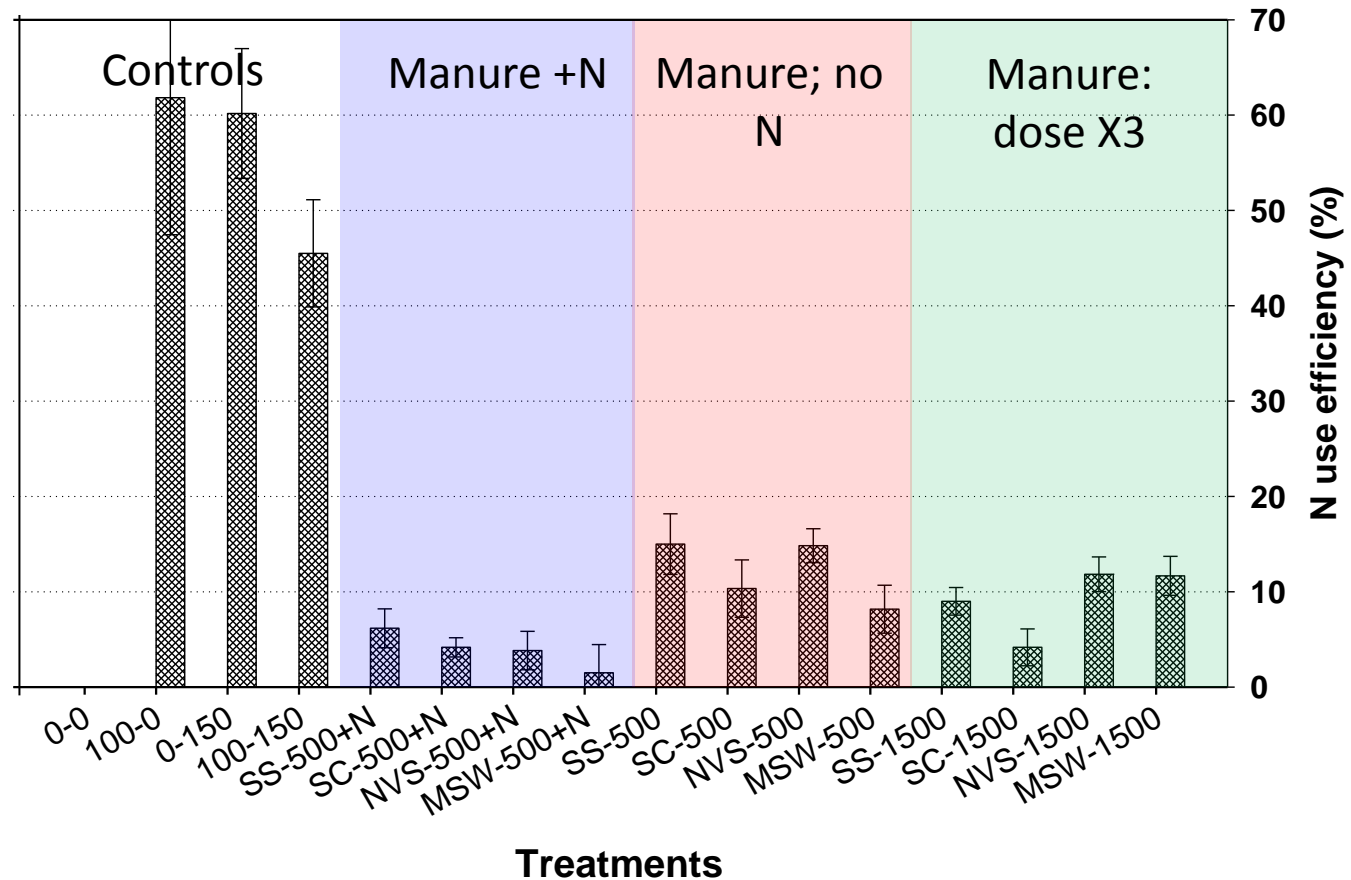
Cumulative N removal in the 3-year (3 corn and 1 wheat) crop biomass and as % of the removal in the on-farm treatment (#4)



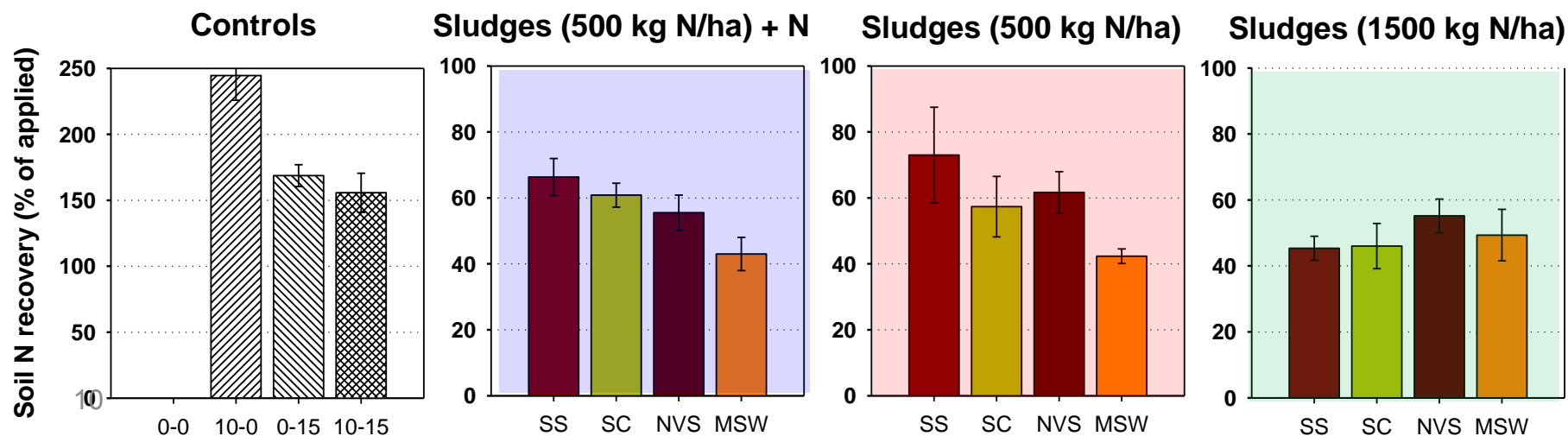
Silage corn - commercial control (10-15)

Year	N (kg/ha)	P (kg/ha)	K (kg/ha)
2011	17	3	24
2012	30	5	37
2013	19		20

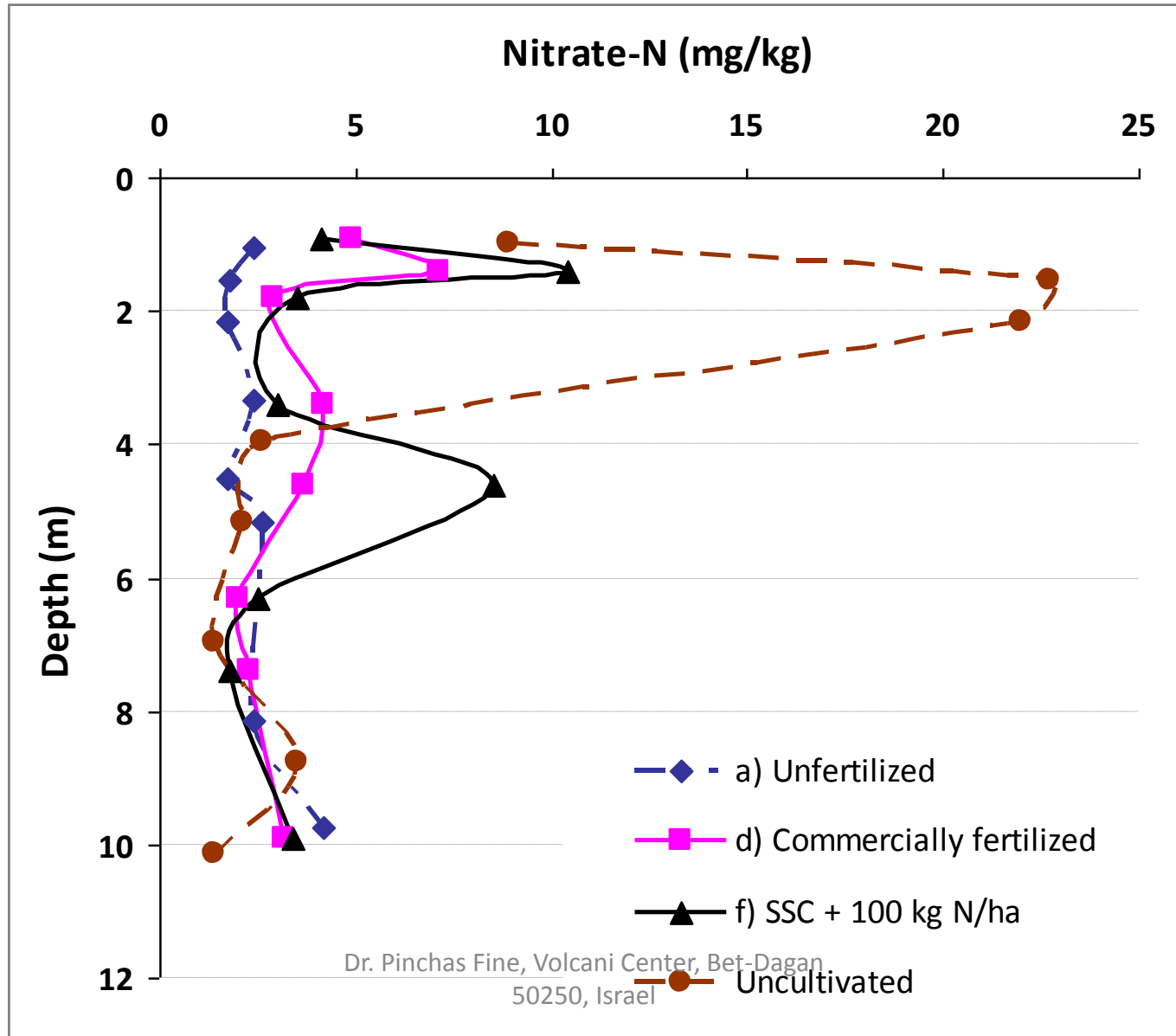
**NUE of the 3 years as % of N applied
(accounting for N recovered in adequate controls)**



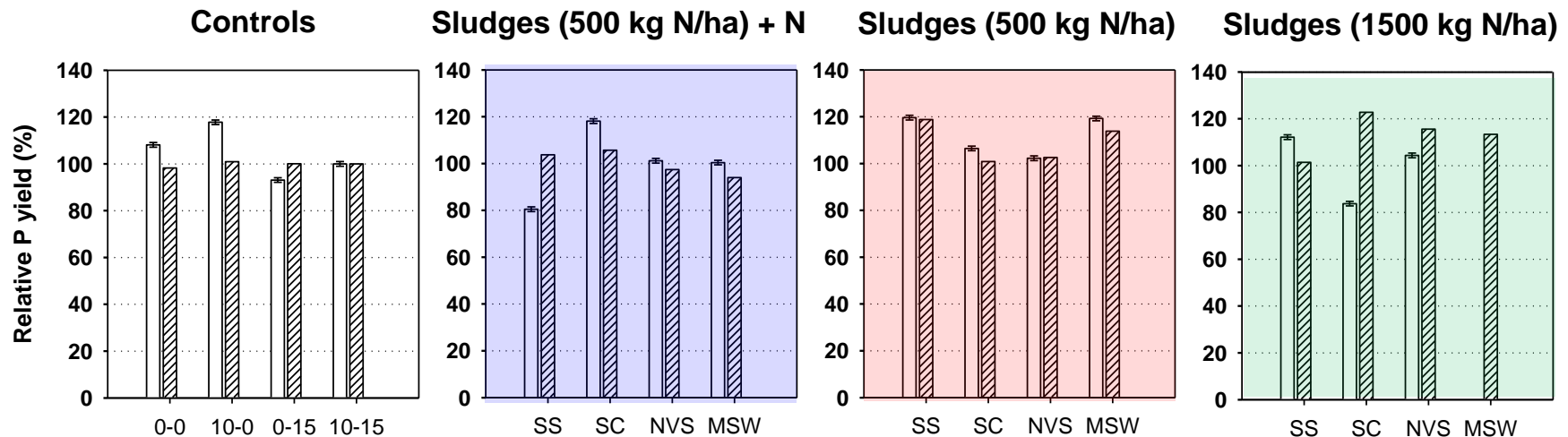
Overall N recovery at the end of the 3 years trial (total N in 4 crops + mineral N in the 1.8-m soil profile)



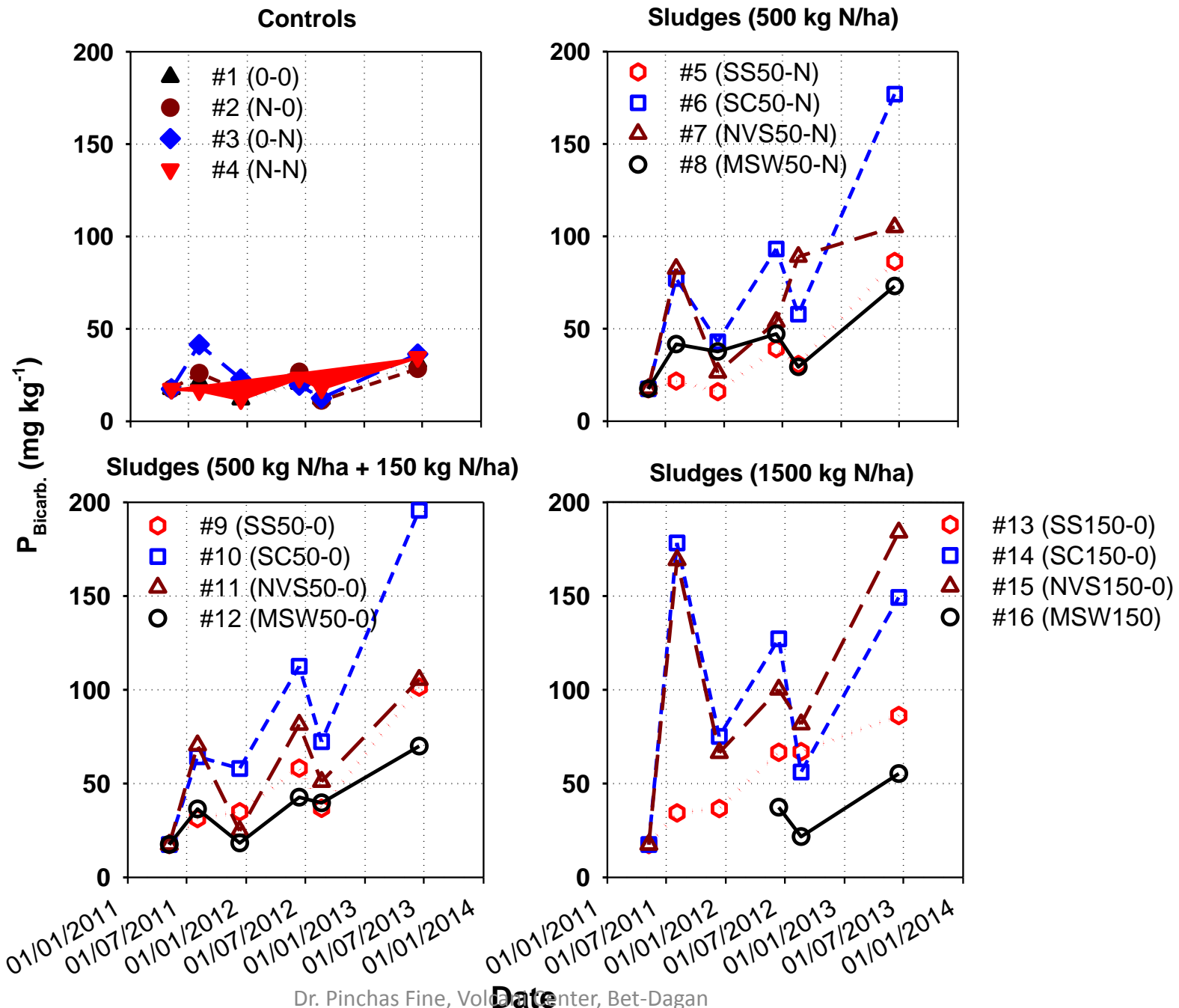
Nitrate-N concentrations down the soil and sub-soil profile in an adjacent area which is under the same crop rotation regime (data from Kurtman et al., 2012)



Amounts of P (as % of on-farm treatment #4) removed by the crops in the first two years of the project



Silage corn - commercial control (10-15)			
Year	N (kg/ha)	P (kg/ha)	K (kg/ha)
2011	17	3	24
2012	30	5	37
2013	19		20



lettuce in 220-L lysimeters

Three soils; 4-8 reps./treatment;

Manures applied twice: in 2011 and in 2012.

Application rates supplied 500 or 1500 kg N/ha/y,
[in () are loads in dry tons/ha]



The treatments in the lysimeter study

Load (Mg/ha)		Load (m ³ /ha)		Load kg N/ha/y	Sludge type	Water	Location	Soil	#
/ 3y	/ y	/ 3y	/ y						
			-	0	-	Tap	Volcani	Sand	1
66	22	138	46	500	SSC	"	Volcani	Sand	2
195	65	315	105	500	NVS	"	Volcani	Sand	3
			-	0	-	Efflu.	Revadim	Sand	4
66	22	138	46	500	SSC	"	Revadim	Sand	5
195	65	315	105	500	NVS	"	Revadim	Sand	6
30	10	168	56	500	Class B	"	Revadim	Sand	7
			-	0	-	"	Revadim	Loessial	8
195	65	315	105	500	NVS	"	Revadim	Loessial	9
			-	0	-	"	Revadim	Clayey	10
66	22	138	46	500	SSC	"	Revadim	Clayey	11
195	65	315	105	500	NVS	"	Revadim	Clayey	12
588	196	945	315	1500	NVS	"	Revadim	Clayey	13

Metals in lettuce (mg/kg dw; summer 2002) in lysimeters

Three soils; 4-8 reps./treatment; **two applications**, in 2011 & 2012.

manures added at 500 or 1500 kg N/ha/y (loads are in m³/ha/y)

Dune sand	As	Cd	Pb	B	Mo	Zn	P	Cu
Control	0.12	0.50 ab	0.09	46 b	0.30 b	37 b	4,867 c	4.2 c
NVS-100 *2	0.17	0.29 b	0.11	75 a	1.01 a	48 b	5,166 bc	7.5 a
Sludge-8 *2	0.13	0.98 a	0.08	44 b	0.20 b	110 a	6,594 ab	6.5 ab
SI comp-22 *2	0.13	0.50 ab	<0.15	39 b	0.38 b	61 b	6,578 a	5.6 bc
<i>P</i>		0.014		<.0001	<.0001	0.0001	0.0018	0.0005

Nahal-Oz (loessial light-brown loam)

Control	0.02 b	0.07 b	0.08	37 b	0.54 b	32	4,805	8.0
NVS-100 *2	0.15 a	0.11 a	0.13	57 a	0.93 a	42	4,565	8.2
<i>P</i>	<0.001	0.031		0.0265	0.0147			

Revadim (vertisol; clayey)

Control	0.13	0.20	0.29	35	0.30 b	46 bc	6,490	9.3
NVS-100 *2	0.22	0.27	0.23	47	0.80 a	40 c	5,140	8.4
NVS-300 *2	0.13	0.27	0.32	46	0.76 a	53 ab	6,920	11.7
SI comp- 22 *2	0.09	0.24	0.31	37	0.38 ab	65a	6,614	9.2
<i>P</i>						0.0006		
Upper bound*	5	1	1.5					

*Min. of Health (4.A.3): ירקות עליים, סלרי, פטריות, צמחי מאכל וצמחי תבלין מיובשים

Quantification levels (mg/kg): Cd: 0.035, Pb: 0.30, As: 0.7

Concentrations (mg/L) of As, Cd, Pb in the lysimeters leachate

Soil & treatment	As (dl = 0.001)				Cd (dl = 0.001)				Pb (dl = 0.001)			
	2011/12	2012	2012 /13	2013	2011 /12	2012	2012 /13	2013	2011 /12	2012	2012 /13	2013
Dune sand (tap wat.)												
Unamended		0.004	0.001	0.000		0.000	0.0000	0.0001		0.000	0.0014	0.0000
NVS-50		0.003	0.001	0.001		0.000	0.0000	0.0001		0.004	0.0002	0.0023
Sludge comp.		0.003	0.001	0.000		0.000	0.0001	0.0001		0.000	0.0011	0.0012
Dune sand (WW eff.)												
Unamended	0.005	0.005	0.005	0.001	0.000	0.001	0.0001	0.0001	0.001	0.001	0.0006	0.0007
NVS-50	0.002	0.004	0.001	0.001	0.000	0.000	0.0000	0.0000	0.000	0.000	0.0005	0.0000
Sludge compost	0.003	0.003	0.012	0.003	0.000	0.000	0.0002	0.0001	0.000	0.001	0.0011	0.0001
Sludge (anaer. dig.)	0.005	0.003	0.005	0.002	0.000	0.001	0.0001	0.0001	0.000	0.000	0.0000	0.0016
Loess scl (WW eff.)												
Unamended	0.005	0.002	0.000		0.000	0.000	0.0001		0.000	0.000	0.0001	
NVS-50	0.003	0.003	0.001		0.000	0.000	0.0001		0.001	0.000	0.0018	
Vertisol c. (WW eff.)												
Unamended	0.004	0.002	0.001	0.004	0.000	0.000	0.0001	0.0000	0.000	0.000	0.0009	0.0035
NVS-50	0.007	0.004	0.001		0.000	0.001	0.0000		0.000	0.005	0.0013	
NVS-150	0.004	0.003	0.003	0.001	0.000	0.000	0.0001	0.0002	0.000	0.001	0.0002	0.0005
Sludge comp.	0.004	0.004	0.001	0.001	0.000	0.000	0.0001	0.0001	0.000	0.000	0.0006	0.0000
Ground water (ceiling)	10 µg/l				5 µg/l				10 µg/l			

Boron and Mo concentrations (mg/L) in the lysimeters leachate

Soil & treatment	Boron				Molybdenum			
	2011/12	2012	2012/13	2013	2011/12	2012	2012/13	2013
Dune sand (tap water)								
Unamended		1.2	1.9	1.6		0.001	0.001	0.001
NVS		1.6	3.4	3.5		0.001	0.001	0.003
Sludge comp.		1.3	2.0	1.7		0.002	0.001	0.001
Dune sand (WW effluent)								
Unamended	1.4	1.7	1.9	1.7	0.005	0.004	0.004	0.003
NVS	2.6	2.2	4.6	4.0	0.004	0.007	0.008	0.004
Sludge compost	1.5	1.7	2.0	1.9	0.003	0.004	0.005	0.007
Class B (Haifa)	1.6	1.5	1.8	1.6	0.005	0.007	0.006	0.012
Loessial sandy clay loam (WW effluent)								
Unamended	1.9	1.7	2.0		0.005	0.004	0.002	
NVS	2.0	1.9	2.3		0.003	0.004	0.002	
Vertisol (clay ; WW effluent)								
Unamended	1.4	1.6	2.1	2.0	0.005	0.003	0.003	0.003
NVS	1.4	1.6	2.1		0.003	0.003	0.003	
NVS (triple dose)	1.5	1.7	2.0	1.9	0.004	0.001	0.003	0.002
Sludge comp.	1.4	1.6	2.0	1.8	0.004	0.004	0.003	0.003
Ground water	-				≤0.070			

Concentrations ($\mu\text{g kg}^{-1}$ dry) of steroidal hormones in the lettuce plants grown in 220-L containers

Sludge type (in 3 soil types)	Estrone		Testosterone	
	Winter	Summer	Winter	Summer
Compost (n=32)	0.89 \pm 1.17	6.26 \pm 4.91	55 \pm 93	34 \pm 51
NVS50 (n=32)	0.76 \pm 0.77	8.35 \pm 5.9	115 \pm 150	28 \pm 44
Class B (n=8)	1.19 \pm 1.44	4.11 \pm 2.29	44 \pm 51	22 \pm 21
NVS150 (n=8)	0.65 \pm 0.71	6.65 \pm 6.59	42 \pm 44	14 \pm 5
Not amended (n=32)	0.41 \pm 0.9	6.78 \pm 3.78	57 \pm 84	38 \pm 52

No statistically significant difference between treatment within each of the 4 seasons



Gracie!

28/5/2014