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ORIGINAL PAPER

AN EVALUATION OF NITROGEN FERTILITY MANAGEMENT IN COMMERCIAL POTATO FIELDS

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Abstract

Nitrogen fertility is an important component for optimum potato yield and quality. Best management practices are necessary in regards to N applications to achieve these goals without applying excess N which may contribute to ground water contamination. Eight potato fields in the Southern San Joaquin Valley were sampled for nitrogen inputs and uptake, tuber and vine dry matter and residual soil nitrate-N. The fields had substantial soil nitrate-N prior to the potato crop. Nitrogen fertilizer was applied prior to planting and in irrigation water as needed based on in-season petiole sampling in accordance with published recommendations. Average total nitrogen uptake was 259 kg ha^{-1} in 55.6 Mg ha^{-1} tuber yield and nitrogen use efficiency was good at 62 percent. Seventy-one percent of the total plant nitrogen uptake was removed from the field in the tubers. Soil nitrate-N increased 8 percent from pre-plant to post-harvest averaged across all fields and was generally situated in the lower soil profile below the effective potato rooting depth. Irrigation timing and amount was generally good at most locations. Pre-plant soil analysis is important information to be used in making N fertilizer recommendations. Rotation crops having deeper rooting growth would be able to utilize nitrogen that remained in the soil profile.

Keywords: Irrigation management, leaching potential, nitrogen, potato.

INTRODUCTION

Nitrogen management has tremendous implications on crop productivity, quality, and environmental stewardship. Nitrogen fertilizer is an important input for potato production. Under application can reduce yield and over application can contribute to unwanted groundwater contamination. Recent reports blame agriculture for the high nitrate levels in the Tulare Lake Basin aquifer. This has prompted additional scrutiny on nitrogen fertility programs in numerous crops grown in the Southern San Joaquin Valley. Nitrates in the soil solution are highly mobile and can be moved beyond the root zone through excessive irrigation. Differences in soil type, potato variety, and potential yield are important considerations when making nitrogen fertilizer recommendations. Soil and in-season plant tissue testing for nitrogen status are a time consuming and expensive process. However, a nitrogen management plan that includes pre-plant and in-season testing along with optimum irrigation management can produce optimum tuber yield and quality and at the same time minimize the movement of nitrogen beyond the root zone and thus the potential for ground water contamination. The objectives of the study are to document if the current nitrogen fertility programs utilized in commercial fields contribute to nitrate leaching and calculate a nitrogen balance of N removal through harvest and N remaining in the soil for subsequent crops.

MATERIALS AND METHODS

In 2016, eight commercial potato fields throughout Kern County, California were monitored for nitrogen status. Fields were selected for different soil types. Soil texture in the selected fields was loamy sand or sandy loam. Most fields were sandy loam soils. Soil samples to 180 cm deep in 30 cm increments were taken for nitrate status before planting and after harvest at four locations in each field. Farming operations used were typical for the area. Potato varieties were chipper and fresh market types. Fields were planted from January through March and harvested from May through July. All fields were sprinkler irrigated.

The 4th upper most leaves were sampled during bulking for N concentration. Four non-destructive instruments were used to assess plant nitrogen content. The Spectrum® FieldScout® CM 1000 NDVI meter uses ambient and reflected light in the 660 and 840 nm wavelengths to calculate a relative chlorophyll index. The Konica® Minolta® SPAD 502 Plus, and the Opti-Sciences® CCM-200 meters clamp on a leaf and utilize 650 and 940 nm wavelengths and 653 and 931 nm wavelengths, respectively, to determine a relative chlorophyll index. The Opti-Sciences® CCM-300 uses the ratio of fluorescence emission at 735 nm and 700 nm as there is a linear response to chlorophyll content in a range from 41 mg m^{-2} to 675 mg m^{-2}.

Vines and tubers were collected, oven-dried, weighed and analyzed for total N content. Tubers were hand harvested from three meters of row. At harvest, vines were separated from tubers and collected. This included leaves, above and below ground stems and some roots. Pre-plant and post-harvest soil samples along with plant and tuber samples were collected from the same area of each field using GPS coordinates. Nitrogen fertilizer application information and ambient irrigation water nitrate levels were supplied by the growers.

Growers used in-season petiole nitrate tests to adjust in-season nitrogen fertilizer applications to maintain petiole nitrate levels within established guidelines. N fertilizer was included in 1 to 14 irrigations during the season depending on the field. Nitrogen partitioning and removal from the field (tuber N concentration on fresh weight basis times yield) was calculated as part of the total N balance. Irrigation water volume was measured using rain gauges. The top of each rain gauge was set at 40 cm above the soil surface. WaterMark® soil moisture sensors were placed at 30, 60 and 90 cm below the soil surface in each field. Soil moisture was measured each minute and hourly averages were recorded on WatchDog® data loggers. Soil, plant, and tuber samples were analyzed for N concentration at a commercial lab.

Soil texture and soil moisture/sensor reading (kPa) relationship were determined in the lab. Soil texture by depth was determined using the industry standard methodology. Field capacity was determined in the lab in small containers with three replications. Soil moisture sensors were imbedded in approximately 400 grams of dry soil in a small cup. The bottom of each cup was perforated to allow excess water to drain. The soil was thoroughly wetted, 24 hours later it was thoroughly wetted a second time, then the sample was allowed to dry. The containers were weighed twice each day. Soil moisture sensor reading and water content by weight at 24 hours after the second thorough wetting was determined to be field capacity. A soil moisture/sensor reading regression line was calculated and used to determine 65% of field capacity.

RESULTS AND DISCUSSION

Leaf nitrogen concentration at bulking ranged from 27 to 50 mg g^{-1} (Table 1). This measurement was made at late bulking and half of the sites were within published guidelines. One site was below the sufficiency range (30 to 45 mg g^{-1}) and three sites were slightly higher than the nutrient sufficiency guidelines (Crozier, et al, 2004). They were in the high range but well below the excessive range. SPAD and CCM-200 chlorophyll meter readings were moderately well correlated (R^2 = 0.58 & 0.49, respectively) with leaf N (Figure 1). Other researchers have found good correlations between meter readings and leaf N (Cohen, et al, 2009; Vos and Born, 1993; Young et al, 1997). CCM-300 and CM 1000 readings were poorly correlated. Leaf nitrogen was not compared to the grower collected petiole nitrogen data used for adjusting in-season nitrogen fertilizer application rates as sampling dates did not coincide.

Table 1. Leaf Nitrogen at Bulking

	N	Chlorophyll Meter			
		CM 1000	SPAD	CCM 200	CCM 300
	- mg g^{-1} -	----------------------------- meter reading	-----------------------------		
1	40.4	64.0	44.7	28.7	461
2	48.5	61.8	52.1	34.4	541
3	35.2	68.3	41.9	29.5	407
4	50.3	65.5	49.2	32.7	480
5	47.2	50.5	49.6	36.2	445
6	26.9	54.3	41.7	22.6	403
7	38.6	53.0	48.0	35.4	429
8	45.5	61.0	46.3	29.8	400
Average	41.6	59.8	46.7	31.2	446
Standard Error	1.59	0.014	0.720	0.954	85

Meter	Linear Equation	R^2
CM 1000	y = 0.031x + 28.4	0.01
SPAD	y = 0.344x + 32.4	0.58
CCM 200	y = 0.420x + 13.7	0.49
CCM 300	y = 2.483x + 342	0.21

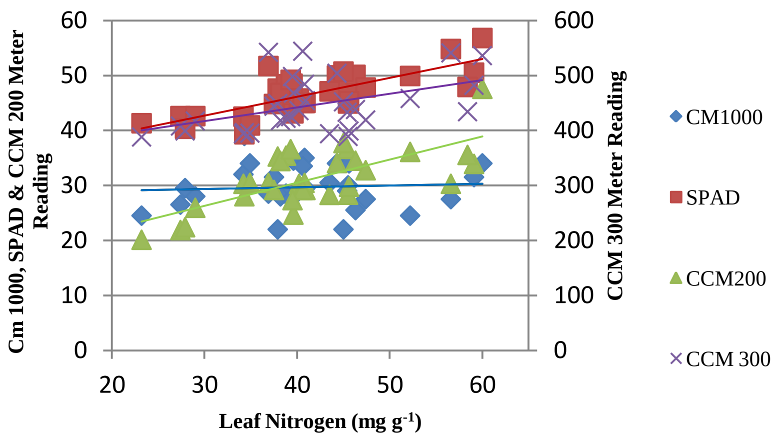

Fig. 1. Chlorophyll Meter Reading versus Leaf Nitrogen.

Vine nitrogen concentration at harvest ranged from a low of 18 to a high of 36 mg g^{-1} (Table 2). Vine nitrogen content ranged from 30 kg N ha^{-1} at site # 3 to 102 kg N ha^{-1} at site #8. The variety planted at site #8 was used because it develops very large plants to protect tubers from high temperatures during July. Vine dry matter accumulation was 1½ times the average as that field and variety were managed for July harvest. Vines at sites most sites were not killed prior to harvest. Averaged across all fields, 29% of the total N was contained in the vines. This is consistent with data reported in one paper (Hopkins et al, 2015) but higher than the 11 to 19% reported by others (Alva et al, 2002; Biemond et al, 1992).

Table 2. Vine Nitrogen at Harvest

Site #	N	Dry Matter	Total Vine Nitrogen		
	-- mg g^{-1} --	-- kg ha^{-1} --	-- kg ha^{-1} --	Standard Error	% of total
1	28.3	3452	97.6	8.43	31
2	22.0	3008	66.1	4.69	35
3	17.7	1711	29.7	4.66	18
4	35.8	2064	73.4	5.37	34
5	24.8	2669	66.6	6.61	41
6	23.1	3292	76.0	5.13	28
7	23.1	3321	77.0	8.28	25
8	22.2	4677	102.4	4.70	25
Average	24.6	3024	73.6	4.20	29

Tuber N concentration ranged from 10 to 22 mg g^{-1} and averaged 17 mg g^{-1} (Table 3). Others have reported tuber N from 3 to 17.5 mg g^{-1} (Waddell, et al, 1999; Kavvadias et al, 2012). Tuber N concentrations from this study are in line with those reported by others (Saffigna et al, 1977; Fontes et al, 2010; Arshadi and Asgharipour, 2011). The wide range of varietal differences in tuber N concentration has been reported by others and needs to be considered when making nitrogen fertilizer recommendations. Total N removed from the field in tubers ranged from 99 to 316 kg ha^{-1} and averaged 184 kg ha^{-1}. Site #8 had the most tuber nitrogen per hectare as it had the second highest tuber N concentration and the most tuber dry mater accumulation. Nitrogen removal is a component of nitrogen fertilizer reporting requirements.

Table 3. Tuber Nitrogen at Harvest.

Site #	N	Dry Matter		Total Tuber Nitrogen	
	-- mg g^{-1} --	-- kg ha^{-1} --	Standard Error	-- kg ha^{-1} --	Standard Error
1	17.9	12429	550	223.7	22.0
2	11.2	11372	754	127.8	17.8
3	15.9	8523	303	135.7	10.5
4	21.7	6744	526	147.2	15.6
5	9.70	10088	757	98.9	14.9
6	17.8	11093	546	197.9	12.6
7	18.1	12554	687	225.9	12.1
8	20.3	15769	1327	315.5	16.8
Average	16.6	11071	514	184.1	12.8

Total plant N uptake ranged from 165 to 418 kg N ha^{-1} (Table 4). Tuber yield ranged from 35.1 Mg ha^{-1} to 78.7 Mg N ha^{-1}. Average tuber yield was 55.6 Mg ha^{-1} with 259 kg N ha^{-1} total uptake. Multiple sources report the N requirement for a 56 Mg ha^{-1} yield is 225 to 270 kg N ha^{-1} of nitrogen fertilizer added (Hopkins et al, 2015; Westerman, 2005). Seventy-one percent of the total N taken up by the plants was removed from the fields in the tubers. This is lower than the 81 to 89 percent previously reported (Alva et al, 2002; Biemond and Vos, 1992) but in line with others (Hopkins et al, 2015; Eghball, 2000) and within reported tuber N range of 48 to 89 percent.

Composted manure was added to some of the fields. Nitrogen availability in the first year from added compost was estimated to be 40 percent of the measured nitrogen. This is the high end of the reported availability range which averaged about 20 percent (Eghball, 2000; Wen et al, 1995; Munoz et al, 2008; Eghball and Power, 1999; Gale et al, 2006; Rosen and Beirman, 2005; Gil et al, 2011; Pettygrove et al, 2009). Nitrogen applied was the total of estimated N from compost, pre-plant fertilizer, native N in the irrigation water and fertilizer N added through the irrigation water.

Nitrogen use efficiency (NUE) calculation is total N uptake divided by added fertilizer nitrogen (TN/FN). NUE was also calculated to include soil nitrate-N in the upper 60 cm (TN/FN+SN) Average NUE-TN/FN across all fields was calculated to be 100 percent plus or minus 5 percent. Individual fields ranged from a low of 68% to a high of 132%. Others reported NUE from three to 144 percent (Zebarth et al, 2004, Cambouris et al, 2008; Joern and Vitosh, 1995; Saffigna et al, 1977; Jong et al, 2003) with an average of 50 to 60 percent average. The lowest NUEs reported were in rain-fed areas and had very different values depending on rainfall from year to year. Average NUE-TN/FN+SN was 62% with a range from 34 to 92%. Tuber yield at site #4 was lower than target yield and the associated pre-plant fertilizer application rate, thus the lowest NUE using either calculation. In contrast, site #8 exceeded target yield with the majority of the added N applied with the irrigation water.

Table 4. Total Plant Nitrogen at Harvest.

Site #	Tuber Yield	Tuber N	Total N Uptake	Total N Applied	Nitrogen Use Efficiency	
					TN/FN	TN/FN+SN
	-- Mg ha^{-1} --	- % of total -	----- kg ha^{-1} -----		------------- % -------------	
1	53.2	69	321	302	106	85
2	53.3	65	206	234	88	44
3	49.8	82	165	168	98	64
4	35.1	66	221	325	68	34
5	58.1	59	165	205	81	48
6	54.5	72	274	249	110	46
7	62.0	75	303	255	119	84
8	78.7	75	418	317	132	92
Average	55.6	71	259	257	100	62

Field averages for pre-plant soil nitrate-N ranged from eight to 31 mg kg^{-1} in the surface 30 cm of soil (Fig. 2). Individual samples ranged from six to 41 mg kg^{-1}. Soil nitrate below 30 cm ranged between three and 41 mg kg^{-1}. All sites averaged between five and 24 mg kg^{-1} for all depths below 30 cm except for the 60 to 90 cm depth at site #2 and at all depths at site #4.

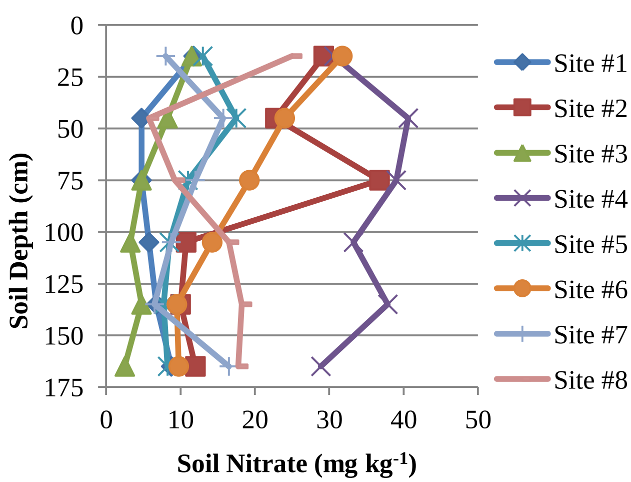

Fig. 2. Pre-plant soil nitrate-N by depth for each field.

Field averages for post-harvest soil nitrate-N ranged from four to 50 mg kg^{-1} in the surface 30 cm of soil (Fig. 3). Individual samples ranged from two to 72 mg kg^{-1}. Soil nitrate-N below the 30 cm depth ranged between one and 38 mg kg^{-1}. A majority of the samples were between five and 15 mg kg^{-1}.

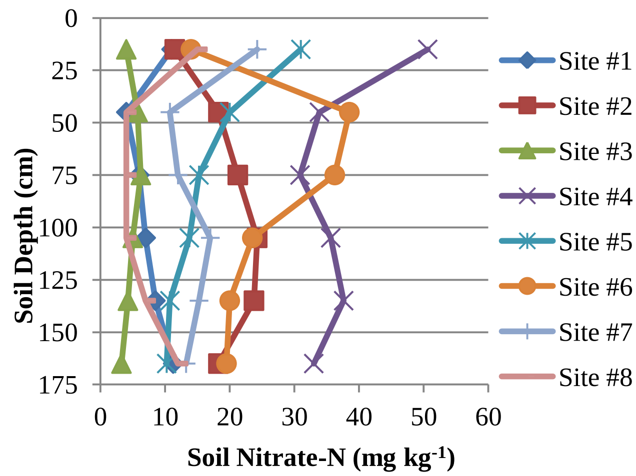

Fig. 3. Post-harvest soil nitrate-N by depth for each field.

Field averages for pre-plant to post-harvest change in soil nitrate-N ranged from -18 to 20 mg kg^{-1} in the surface 30 cm of soil (Fig. 4). Individual samples ranged from -82 to 39 mg kg^{-1}. The field average range of change of soil nitrate-N in the 30 to 60 cm depth was from -10 to 15 mg kg^{-1}.

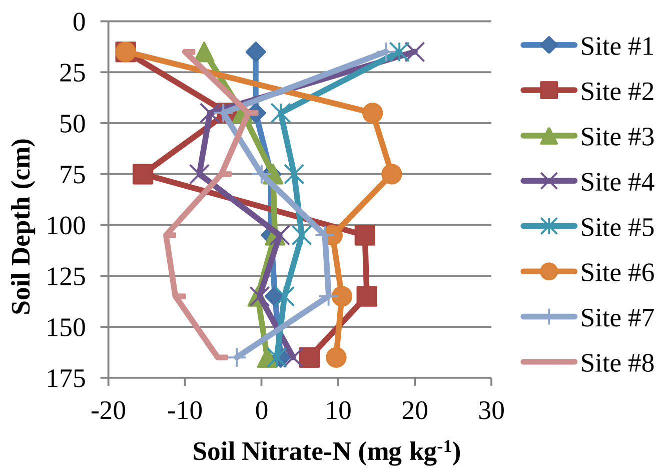

Fig. 4. Difference between pre-plant and post-harvest soil nitrate-N by depth for each field.

Averaged across all fields pre-plant soil nitrate-N was 20 mg kg^{-1} in the surface 30 cm (Fig. 5). Pre-plant soil nitrate-N in the 30 to 60 cm and the 60 to 90 cm depths averaged 17 mg kg^{-1} and in each 30 cm depth increment from 90 to 180 cm nitrate-N levels were between 12 and 13 mg kg^{-1}. Averaged across all fields post-harvest soil nitrate-N was 20 mg kg^{-1} in the surface 30 cm. Post-harvest soil nitrate-N in the 30 to 90 cm depth averaged 14 mg kg^{-1} and in each depth increment from the 90 to180 cm soil nitrate-N was between 12 and 13 mg kg^{-1}. Averaged across all fields there was no change soil nitrate-N in the surface 30 cm. The was a small (3 mg kg^{-1}) but statistically significant difference increase in soil nitrate-N in the 90 to 120 cm and 120 to 150 cm depths. The difference between pre-plant and post-harvest soil nitrate-N at all other depths was not statistically different.

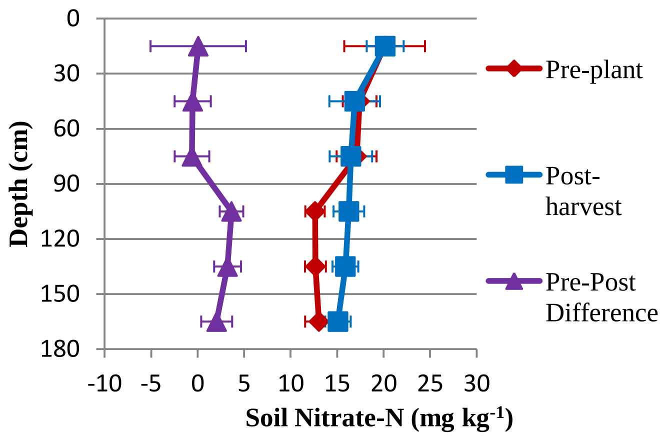

Fig. 5. Pre-plant, post-harvest and change in soil nitrate-N averaged across all fields.

A substantial amount of nitrogen was in the soil profile prior to planting. Soil nitrate nitrogen in the surface 60 cm ranged from 88 kg ha^{-1} at site #3 to 319 kg ha^{-1} at site #4. Averaged across all fields, the highest amount (168 kg ha^{-1}) was in the 0 to 60 cm depth then decreased in the 60 to120 cm depth (133 kg ha^{-1}) and continued to decline to 115 kg ha^{-1} in the 120 to 180 cm depth (Table 5). Potato roots can grow to a depth of 90 cm but are generally concentrated within the upper 30 to 45cm (Iwama, 2008; Ahmadi et al, 2011; Anon, 1983). Rooting depth for various other crops used in these potato rotations include carrots with a rooting depth of 90 to 120 cm and wheat or corn with a rooting depth of 120 to180 cm (Iwama, 2008; Thorup-Kirstensen et al, 2009).

Table 5. Surface Soil Profile Nitrate-N Status.

Site #	0-60 cm Depth			60-120 cm Depth		
	Pre-plant	Post-harvest	Difference	Pre-plant	Post-harvest	Difference
	kg ha^{-1}					
1	74	67	-7	47	58	11
2	233	133	-100	213	204	-9
3	88	44	-45	36	50	15
4	319	379	59	324	298	-26
5	137	228	92	87	130	43
6	250	235	-15	150	268	118
7	106	157	50	93	130	37
8	138	85	-53	115	36	-80
Average	168	166	-2	133	147	14

Site #	120-180 cm Depth			0-180 cm Depth		
	Pre-plant	Post-harvest	Difference	Pre-plant	Post-harvest	Difference
	kg ha^{-1}					
1	69	88	19	190	214	24
2	99	188	90	544	525	-19
3	32	34	1	157	128	-29
4	299	316	17	942	993	51
5	72	94	22	296	452	157
6	86	177	91	486	680	194

7	103	128	25	302	414	112
8	161	85	-76	414	206	-208
Average	115	139	24	417	452	35

Substantial nitrate-N remained in the soil following harvest. There was 166 kg N ha^{-1} in the surface 60 cm averaged across all fields. The amount varied greatly between fields ranging from 44 to 379 kg ha^{-1}. There were decreasing amounts, about 30 and 20 kg ha^{-1} in each depth increment, measured in the 60 to 120 cm and the 120 to 180 cm depths, respectively. Site #4 with the highest level of nitrate-N also had the most variability in the samples. For example, the pre-plant 30 to 60 cm depth samples ranged from 5 to 87 mg N ha^{-1}. The average was 41 mg N ha^{-1} with a standard error of 18.6 for this depth. The change in pre-plant to post-harvest soil nitrate-N ranged from -208 to 194 kg ha^{-1} with an average of 35 kg ha^{-1} for the 180 cm profile. The initial moderate soil nitrate-N content (137 kg ha^{-1}) in the surface 60 cm at site #5 had one of the highest levels (228 kg ha^{-1}) following harvest. This field had the highest increase in soil nitrate-N in the surface 30 cm. In contrast, a decrease in nitrate-N was observed at each depth at site #8 resulting in a substantial decrease in soil nitrate-N. Two sites had a moderate decrease (< -30 N kg ha^{-1}) and two sites had a moderate increase (< 50 kg N ha^{-1}) and three sites had a substantial increase (> 100 kg N ha^{-1}). A mass balance of nitrogen was calculated for each field. Total N available was the sum of pre-plant soil nitrate-N and added nitrogen from all measured or estimated sources (Table 6). Total N uptake and residual was the sum of N in vines, tubers, and post-harvest soil nitrate-N. Averaged across all fields the total available and total uptake and residual were not substantially different. There were differences for individual fields as unaccounted for N ranged from -11 to +22% of the total uptake. There was only 26 kg ha^{-1} nitrogen unaccounted for when averaged across all fields. There are some assumptions and omissions made in the calculation. Only nitrate-N was measured in the soil. It is assumed that soil NH_4^+ was minimal. The assumed N availability from added compost was discussed previously and all available N from compost was included in the N applied total. Compost was applied prior to pre-plant soil sampling. Some mineralized N from compost would have also been measured as part of the pre-plant soil sample. Care was taken to collect all tubers and plant material during the hand harvest. Small tubers that would not have been collected with a mechanical harvester were included in the tuber yield. Roots and small stems that separated from the main vine were also not collected. No measurements of organic N, immobilization, or volatilization were made. Nitrate-N in irrigation water was assumed to be at the same concentration all season.

Table 6. Nitrogen Balance.

Site #	Total N Available	Total N Uptake & Residual	Unaccounted Nitrogen		
	--------------------------- kg ha^{-1}	--		Standard Error	% of Total N
1	493	535	42	46	8
2	778	731	-47	84	-6
3	325	293	-32	45	-11
4	1267	1214	-53	178	-4
5	501	618	117	54	19
6	735	954	219	80	13
7	558	717	160	74	22
8	731	624	-107	76	-17
Average	673	711	26	33	4

Soil moisture and irrigation amounts are shown for each site in Figure 6. Optimum soil moisture for potato growth and quality is between field capacity and 65% of field capacity (King and Stark, 1997). Soil moisture sensors were place to monitor water status in and below the effective rooting zone. Field soil moisture at the 90 cm level remained fairly constant at field capacity at sites #1 and #4. There was a general drying trend over the season in the upper 60 cm of soil at these sites. There were statistically significant increases in soil nitrate-N at the 150 to 180 cm depth at site #1 and in the 60 to 90 cm depth at site #4. There were no other significant differences at the other depths. These sites had a small increase in soil profile nitrate-N. A small increased difference in nitrogen balance for sites #1 and a small decreased difference at site #4.

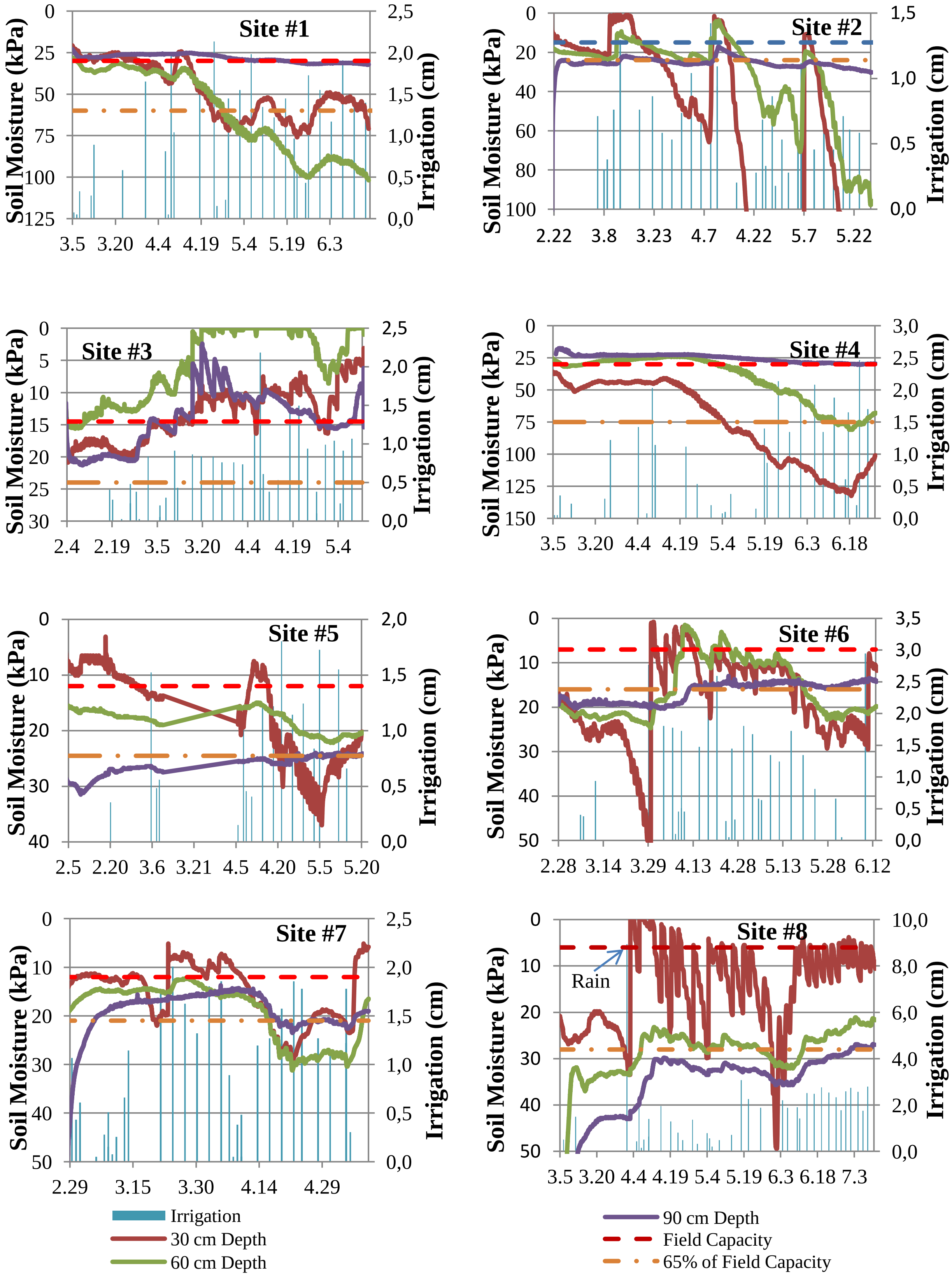

Fig. 6. Soil moisture and irrigation for each site.

Sites #3 and #5 had increases in soil nitrate-N in the surface 30 cm. There were also small but statistically significant increases in the 60 to 90 cm depth at site #3 and at the 60 to 120 cm depth at site #5. There was no significant change in soil nitrate-N at any other depth at these sites. Soil moisture at site #5 below 30 cm remained below field capacity even when soil moisture at the 30 cm depth exceeded field capacity at times during the growing season. There was a gap in soil moisture data due to a battery malfunction at site #5.

Although there was a net no change in soil nitrate-N throughout the soil profile at site #2, there was a significant increase in soil nitrate-N below 90 cm offset by a significant decrease of soil nitrate-N in the surface 90 cm. This site had wide fluctuations in soil moisture and had the coarsest soil of any of the sites. At three times during the season, soil moisture in the surface 60 cm exceeded field capacity. Site #6 also had a decrease in soil nitrate-N in the surface 30 cm but a large increase was measured in each depth below 60 cm resulting in a large increase in soil nitrate-N. Site #7 had increases in soil nitrate-N in the surface 30 cm and in the 90 to 150 cm depth. Site #8 had a significant decrease in soil nitrate-N in the 30 to 150 cm depth. A substantial amount of nitrate-N was removed from the soil profile through plant and tuber uptake at this site. Soil moisture measured at the 30 cm depth cycled up and down with each irrigation and drying cycle. A substantial rainfall event increase soil moisture above field capacity and increased soil moisture at the 60 and 90 cm depth. This site is an excellent example of good irrigation management.

Sites #2 and #3 had a similar near zero change in soil profile nitrate-N and a similar slight decrease measured as unaccounted N, however site #2 had more added N, 3.5 times the amount of pre-plant soil nitrate-N in the soil profile and 4 times the amount post-harvest than site #3. Leaf N, vine N concentration and content were higher at site #2 than site #3. Vine N concentration was in the high range at site #2. Nitrogen removed from the field in tubers was equal as tuber N concentration was lower at site #2 but had a higher tuber yield. These sites did not have the same variety. NUE, with either calculation, was higher at site #3. Soil moisture at both locations exceeded field capacity occasionally at site #2 and for a prolonged time at site #3. A comparison of where the soil nitrate-N was pre-plant and post-harvest is telling (Fig. 7). Even though site #3 had higher soil moisture levels that needed for optimum plant growth the low initial soil N level and timely application of in-season N fertilizer contributed to better N management. The higher nitrate-N levels at site #2 and repeated saturation of the surface soil profile contributed to substantial movement of nitrate from the surface 90 cm to deeper in the profile. Site #2 could benefit from improved nitrogen management.

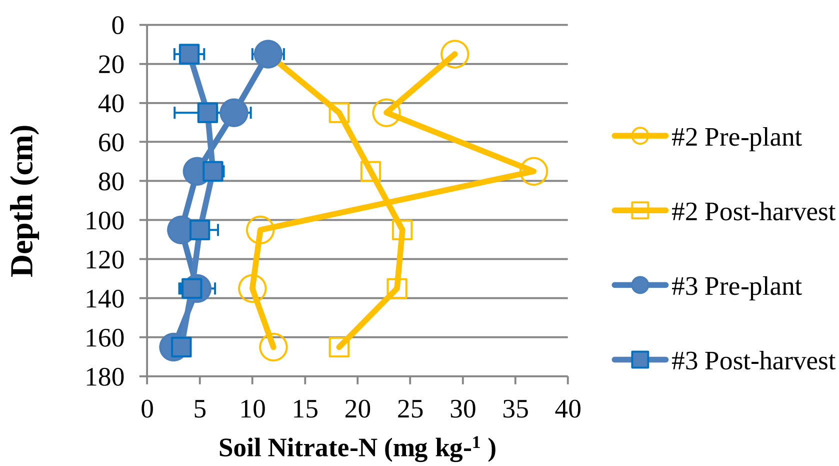

Fig. 7. Sites #2 and #3 Soil Nitrate-N

CONCLUSIONS

The fields that were sampled had substantial soil nitrate-N prior to the potato crop. It is imperative that pre-plant soil nitrogen be measured and that information be incorporated in nitrogen fertility recommendations. In-season petiole sampling for nitrogen level helped in scheduling in-season nitrogen fertilizer applications. Total nitrogen required for the yields obtained in the Southern San Joaquin Valley were consistent with previously published data and nitrogen use efficiency including surface 60 cm soil nitrate was a good 62%. NUE of added nitrogen was excellent at 100%. Averaged across all fields there was an 8% increase in soil nitrate from pre-plant to post-harvest. The small increase was in the lower profile. These results are similar to those previously reported for potato production in this area (Marsh, 2016). However, typical rotation crops with deeper rooting growth would be able to take up the nitrogen. Irrigation scheduling is most critical to control movement of nitrate deeper into the soil profile. Where irrigation water did not move into the lower profile, soil nitrate remained in place.

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