Is it worth subsoil testing for Nitrogen?

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KEY MESSAGES

More N at in the subsoil than previously realised

Mineral N at depth can be used by crops but root uptake depends on subsoil constraints and leaching

Subsoil N should be factored into the N fertiliser application decisions on most soils without root constraints

AIMS

In WA, soil testing for mineral N (ammonium plus nitrate) has traditionally been taken from the top 0-0.1 m. Farmers and advisors are now interested in deeper soil testing, in order to know how much mineral N occurs at depth and what this may mean in terms of fertiliser N application decisions. Accounting for topsoil and subsoil test level in N fertiliser use varies markedly among growers and advisors depending on; their own historic applications; use of nitrogen decision support tools (N-DSS's) such as Yield Prophet simulations or SYN. Other growers use approximate total soil profile N and then add N fertiliser required to reach target yield (i.e. 45 kg N/ha for 1 t/ha of grain).

The main question this paper is addressing is "Do I need to soil test to depth for better N decisions?"

To answer this we needed to understand: 1. Where in the profile the subsoil N occurs and if it is related to topsoil N, 2. How effective is the subsoil in supplying N for the crop – which depends on root access to subsoil N as affected by subsoil constraints and N leaching, 3. What does this mean for N recommendation systems based on soil testing? and 4. Given the seasonal interaction with yield response, will the subsoil N test results reduce the errors in recommendations enough to justify this extra complexity, cost and effort?

METHOD

Soil samples

Soil data was collated from 474 sites covering northern, eastern and south coast agricultural regions taken during 2000-2012 near the start of the growing season (April-May). The soil information came from CSIRO and DAFWA projects. The depth to which soils were sampled varied from 0.3 m to greater than 1.2 m, but less than half the sites were sampled to 1.2 m (Table 1). There was a large range of sampling depth intervals therefore soil depths had to be grouped to allow for comparative analysis. Samples were analysed for OC, NO_3, NH_4, pH, EC (and many for P, K, S) and classified into WA soils groups (Schoknecht, 2002). The detection limit of N as NO_3 and NH_4 is 1 ppm and is often reported as <1 by CSBP, therefore all values =<1 were rounded down to 0.

APSIM

APSIMv7.4 was used to assess the value to wheat yield of deep N and its interaction with soil type and season. To do this N was added to the profile in a 0.2 m layer at depth (i.e. 0.2-0.4 m) and the effectiveness of N calculated as the additional yield from this additional N (kg grain/kg N). The relative effectiveness was calculated at the effectiveness of N at a depth compared with the effectiveness of N in the top-soil (0-0.2 m layer). APSIM was then used to simulate the effect on wheat yield of the additional N in a layer for different depths down the profile, mineral N profiles, soil types, locations and seasons.

We modelled wheat growth at Merredin and Northam using historical rainfall data from 1911 to 2011 (average GSR May-Oct of 224 mm, 337 mm respectively) for a sand, loam and clay. Each soil was simulated with unconstrained roots, roots constrained to depth (i.e. acid profile) and roots constrained only in the 0.2-0.4 m layers (i.e. acid band or hard pan soils). The soils varied in their plant available water capacity (PAWC), and soil water conductivity (SWCON) which determines leaching potential. The soils used were: a clay soil which had a PAWC of 125 mm and SWCON of 0.3, a loam which was a deep loamy duplex with a PAWC of 113 mm and SWCON of 0.5, and a sand which was a pale deep sand with PAWC of 79 mm and SWCON of 0.7. The mineral N in the soil profiles to 1.2m were set to a low initial mineral N (28 kg N/ha, with 15 kg N/ha in the 0-0.2m layer) or medium mineral N (58 kg N/ha, with 37 kg N/ha in the 0-0.2m layer) with additional 10 or 20 kg N/ha as NO3 added to the 0-0.2 m, 0.2-0.4 m, 0.4-0.6 m, 0.6-0.8 m, 0.8-1.0 m and 1.0-1.2 m layers.. The soil profiles were reset to these values on the 1 May just prior to sowing to remove the effect of mineralisation.

Wheat *cv.* Wyalkatchem was sown at 100 plants/m^2 between the 1 May and 30 June after 15 mm rainfall over 10 days, otherwise they were sown on 30 June (average sowing date was 21 May in Merredin and 16 May in Northam). The wheat crop was fertilised with 14 kg of Nitrate N/ha at sowing. Every year was simulated as wheat without residual effects from previous years by resetting soil water reset to wheat crop lower limit on 1st January each year.

RESULTS

Profile soil data

On average the measured soil profiles had 135 kg N/ha as mineral N to 1.2m depth. There was an average 98 kg N/ha as NO_3 in the profile to 1.2 m with 30% of this in the top 0-0.1 m and 58% in the 0-0.4m (Table 1). There was 37 kg N/ha as NH_4 in the soil, with only 22% of this in the 0-0.1m and 29 kg N/ha of NH_4 was below 0.1 m. Therefore there was 98 kg of the mineral N/ha (or 73% of the profile total) measured in the soil profile below the standard 0-0.1 m soil test.

The mineral N was highly variable across soils, seasons and locations (see high standard deviation particularly at depth). Some differences in soil groups were: Higher than average mineral N at 0-0.1m and 0.1-0.2 m layer occurred in the shallow gravel (8 sites), duplex sandy gravel (12 sites) and shallow loamy duplex (31 sites). The clay soils (55 sites), loamy earth (28 sites) and gravelly loam (7 sites) also tended to have higher subsoil NO_3 below 0.4 m. There were a large percentage of sites with subsoils (> 0.2 m depth) which had greater than 10 kg N/ha (48-65%) or 20 kg N/ha (15-35%) mineral N in a layer .

Table 1. Mineral N at depth in the soil profiles, from samples taken in April-May prior to sowing crops collected over 2000-2012.

Depth interval (m)		0-0.10	0.1-0.2	0.2-0.4	0.4-0.6	0.6-0.9	0.9-1.2
Number of sites		474	467	352	381	284	221
N_NO3	ppm (mg/kg)	19.0	7.8	5.2	3.6	3.1	3.6
	kg N/ha [A] in layer	29	12	16	11	14	16
N_NH4	ppm (mg/kg)	6.3	3.4	2.3	1.5	1.4	1.6
	kg N/ha[A] in layer	8	5	7	4	6	7
Mineral N	kg N/ha in layer	37	17	23	15	20	23
	Cumulative kg N/ha to stated depth	37	54	77	92	112	135
	Stdev (kg N/ha)	29	11	13	15	21	25
	% sites > 10 kg N/ha [B]	89%	67%	48%	59%	65%	61%
	% sites > 20 kg N/ha[B]	68%	24%	14%	31%	25%	35%

(A assuming Bulk density of 1.5), B % of sites measured to that depth not of the 474 cores)

If there is a strong relationship between topsoil N and profile N, then it is unnecessary to sample to depth and subsoil N can be factored in based on measurements in the topsoil. For these sites, plotting the mineral N in the topsoil versus that in the profile (to 1.2m) indicates there is on average 2.35 times more mineral N in the profile but there are many outlier values and a large amount of scatter (r^2=0.49). Some of the high subsoil outliers were clayey soils in the eastern Wheatbelt, and when removed the r^2 increased to 0.62 (y=2.21x). However there is higher correlation between the mineral N in the topsoil and that in profile to 0.4 m and 0.6 m with 1.6 times the N in the 0-0.4 m as in the 0-0.1 m (r^2 = 0.79), 1.9 times the N in the 0-0.6 m (r^2=0.69).

Effectiveness and Relative Effectiveness of additional N

For the clay soil with no root constraint, the effectiveness of an additional 10 kg/ha of N in the 0-0.2m layer was on average 34 kg/ha grain per kg N/ha (Table 2). The modelled effectiveness of the additional N in the 0-0.2m layer is higher in the clay and loam than the sand and higher in Northam than Merredin. When a root constraint is introduced, it reduces the effectiveness of N in the topsoil for the sand at both locations and loam at Northam. The effectiveness of N in the 0-0.2m layer is highly variable and seasonally dependent (Standard deviation in brackets in table 2).

Fig 1 shows the relative effectiveness of an additional 10kg N/ha in the 0.2-0.4, 0.4-0.6, 0.6-0.8, 0.8-1.0 or 1.0-1.2 m layers compared with the 0-0.2 m layer, averaged over 100 years. The relative effectiveness of N decreases with depth and is highly variable with season. When there are no root constraints there is still significant contribution of N at

1.0-1.2 m layer of 20-60% relative effectiveness. The N is less effective at depth in sandy soils at the higher rainfall location, possibly due to leaching before the roots can access it.

Table 2. The 100 year average N effectiveness (kg grain / Kg N) in the 0-0.2m layer for 10kg N/ha in a low N profile soil (28 kg N/ha) and a medium soil profile (56 kg N/ha) with low fertiliser application at sowing (14 kg N/ha) with standard deviation in brackets.

N in soil	Soil	Merredin		Northam	
		No constraint	Layer constraint	No constraint	Layer constraint
Low soil N (28kg N/ha)	Sand	14 (12)	5 (5)	18 (12)	5 (5)
	Loam	28 (9)	24 (10)	32 (6)	18 (12)
	clay	29 (10)	30 (9)	34 (6)	32 (8)
Medium soil N (56 N kg/ha)	Sand	5 (6)	3 (4)	8 (8)	3 (3)
	Loam	19 (8)	20 (11)	25 (8)	18 (12)
	clay	19 (7)	20 (8)	23 (7)	26 (8)

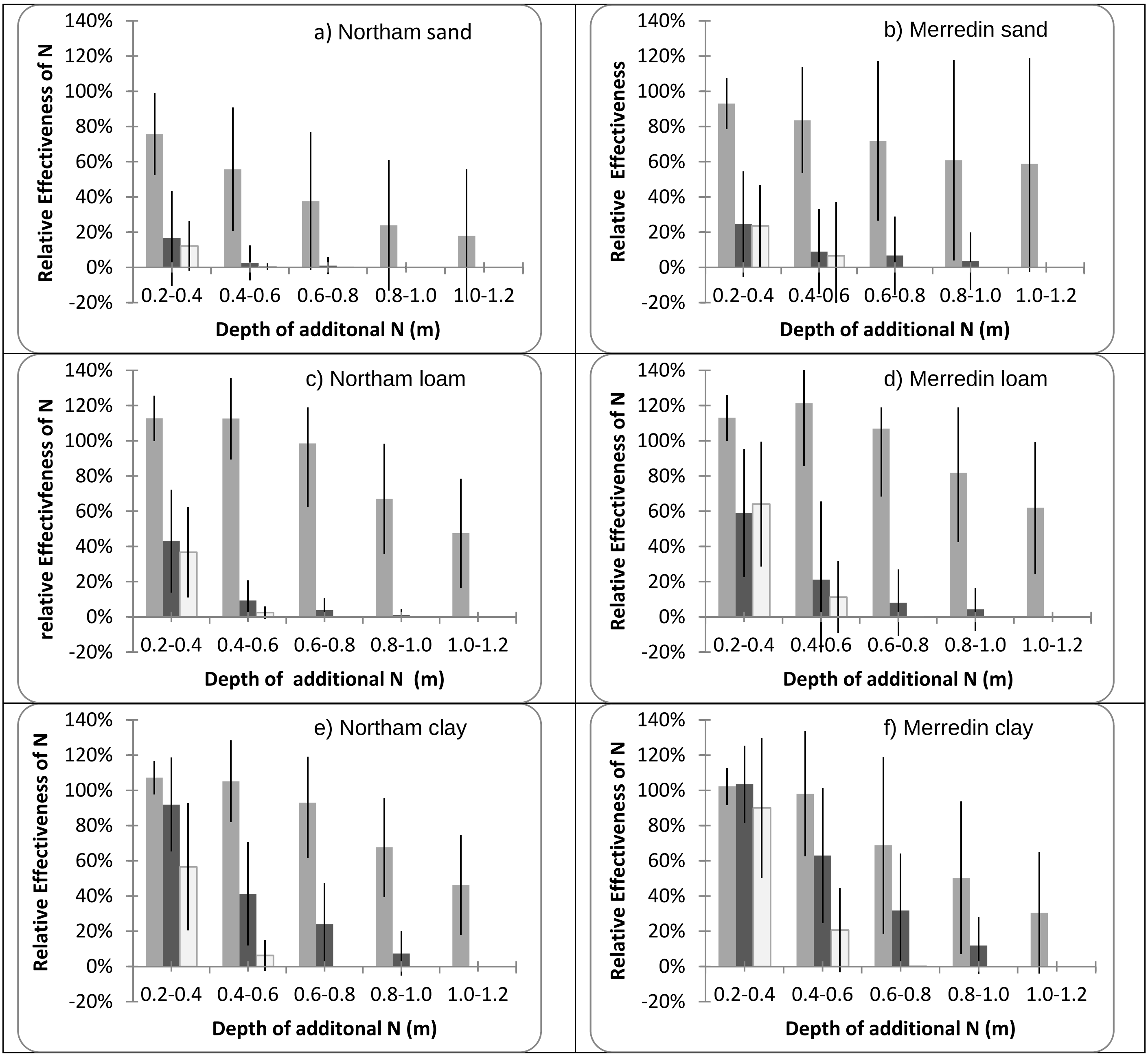

Fig 1 Relative effectiveness of 10 kg/ha N at depth for the low N profile in the sand, loam and clay soils, at Merredin and Northam with no root constraint (■), constraint in layer (■) and constraint down profile (□) with standard deviation as error bars.

When roots are constrained at a layer, as in an acid band or hardpan, the relative effectiveness of N at depth is greatly reduced (Fig 1). The roots are still able to grow to maximum depth in most years but they are delayed in the time at which they reach a certain depth and therefore have reduced effectiveness at taking up deep N. The combination of this plus leaching in the sand and loam and/or higher rainfall location has reduced the relative effectiveness to 20-40% in the 0.2-0.4 m layer and less than 20% in the deeper layers. In the heavier textured soil (clay) the N in the 0.2-0.4 m layer was almost as effective as the surface N, but sharply reduced to 40-60% in the 0.4-0.6 m layer, and to less than 20% in the next layer.

When the roots are constrained down the profile, as occurs in an acid wodjil soil, the ability of the roots to uptake N at depth is greatly reduced. In this example the roots seldom grew below 0.6 m, thus any N deeper than this was not accessible.

Implications for N recommendations?

If N fertiliser recommendations use a mineral N soil test value, plus other adjustments for previous crop type and soil organic carbon, required to meet target yield, then there may be a way to include subsoil N. This may be done by using the soil test value in the subsoil layers and weighting its value according to its relative efficiency at depth depending on subsoil constraint, soil type and location.

From the measurements summarised above, it is likely in many situations that there is an additional 40 kg N/ha in the 0.2-0.6 m layer compared to just the 0-0.2 m measurement (54 kg N/ha on average). For heavier soils, loam and clay, without root constraints 100% of this additional N could be included in the total available soil N when calculating the N recommendation. However, for a sand without root constraint, only ~70% of the additional N could be included. This is because from Fig 1a,b, the N at 0.2-0.6 m depth is 60-90% as effective as N in the 0-0.2 m layer. When root constraints occur, the effectiveness of the N drops dramatically and inclusion of a deep soil N contribution seems only justifiable for the heavier soils.

There is also potentially another 43 kg N/ha in the 0.6-1.2 m layer, however for soils with constrained roots this unlikely to be taken up. For soils without root constraint the N in the 0.6-0.8 layer should be included for loam and clay and for sand at low rainfall locations (70-100% relative effective) but still might be included on the sand at high rainfall location using a 40% relative effectiveness. The N below 0.8m on the soils without root constraint may be included in some years (see Fig 1 for a range of relative effectiveness).

It must be noted that deep N may already be accounted for in some N recommendation if a DSS was used. Many nitrogen decision support tools (e.g. SYN, NuLogic) were created from nutrient response trials over a range of soil, seasons and locations. Those trials necessarily included whatever deep soil N the crops could access and so the responses will be weighted by that contribution from deep N. For tools such as Yield Prophet®, the N at depth is usually measured and included in the model, however the roots for most of the soils in Yield Prophet are set to unconstrained growth.

CONCLUSIONS

There is more mineral N in profile that thought, with 135 kg N/ha mineral N in the profile to 1.2 m and 98 kg N/ha (or 72%) of this below 0.1m, but this is highly variable across the sites. On soils without subsoil constraint, mineral N deeper in the profile even down to 1.2 m, has a high relative effectiveness in all soils and locations and should be accounted for in fertiliser decisions. If constraints are present, then on heavier soils (clay and loam) it still may be worth accounted for N up to 0.6 m but with a lower relative effectiveness.

To account for N up to 1.2 m requires deep soils tests as it cannot be estimated from topsoil N, due to weak correlation(r^2=0.49). A moderate correlation between the N in 0-0.1 m and that to 0.6 m (r^2=0.69) may mean deep soil testing is not required in some circumstances; however it will provide a more accurate profile N value.

Subsoil constraints reduce the ability of crops to access deep nitrogen and it is therefore important to diagnose, understand and adjust for them. Understanding of presence of deep N and subsoil constraints may improve fertiliser decision however the cost of sampling to depth and analysis to depth must be considered..

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