Effects of nitrogen-fixing microbial product TwinN, and natural biostimulant AgriKelp on potatoes grown under organic regimes in Herefordshire, England - 2008

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Introduction

The new microbial product TwinN claims to increase nitrogen availability in crops by boosting the numbers of nitrogen-fixing microbes, acting both in the soil and within the plant itself. There is nothing new about nitrogen-fixing microbial products as such, but they are reported to give inconsistent and unreliable results. Their problem would seem to be the viability and consistency of the microbial population being supplied to farms in liquid form. However, TwinN offers something new, as it is the only such product available in freeze-dried form, thus claiming to provide a more reliable supply of effective microbes to farmers and growers. Although there are already claims that TwinN is being used to boost yield and quality of crops in Australia and Southern Africa, there has been no data published in the scientific literature.

In 2007, two independent field experiments clearly demonstrated that TwinN could be used to improve yields of potatoes. The experiments were in cv. Milva and Valor, grown under an organic regime and yielding 27 and 34 t/ha respectively. TwinN was shown to give consistent yield increases of between 15 and 30%, and since these increases were in the weights of larger tubers, it showed that the availability of nitrogen to the crop had been improved. Two applications of TwinN had more than doubled the number of larger tubers over 45mm in both varieties.

The average national yield for potato tubers is 45 t/ha, but closer to 25 t/ha in organic regimes. As such there is greater scope to improve the yields of Organic potatoes purely through increasing the availability of nitrogen. Organic manures may offer a partial solution, but potato crops can respond to much higher levels of available nitrogen than manures alone can supply. Although current RB209 (Defra, 2000) recommends a maximum rate for fertiliser nitrogen on potatoes as 270 kgN/ha, several authors have reported that potatoes can respond to levels higher than this. However, there are pressures, other than the price of fertiliser, moving to reduce the amount of mineral nitrogen applied, which of course is zero in Organics.

In 2008, two robust field experiments were designed primarily to confirm the effectiveness of TwinN seen last year. Treatments tested TwinN applied both alone and in mixture with the new biostimulant, AgriKelp from FarmFos Limited. AgriKelp is a mixture of natural plant ingredients designed to enhance the activity of TwinN microbes both in the spray tank and during application. It contains plant sugars as added nutrition to encourage establishment of the organisms, and natural surfactants to encourage spray cover and leaf uptake. AgriKelp is also a biostimulant in its own right, and tested here to establish its effectiveness in improving the availability of nitrogen in organic potatoes. AgriKelp and TwinN are both registered as permitted inputs in Organic farming regimes.

Field Histories

At Brooke House Farm, Avenbury, Bromyard, Herefordshire, Roadside field (OS Map Ref: SO 667 525) was planted to potatoes, cv. Valor on 15th May 2008. Previous cropping in this field was two years of clover grass ley (2006 & 2007) following wheat in 2005.

At Foxhalls Farm, Sollers Hope, Herefordshire, Pond field (OS Map Ref: SO 632 318) was planted with cv. Amarosa on 17th May 2008. Previous cropping was peas in 2007 following mixed vegetables in 2006.

The soils at both sites are typical argillic brown earths of the Bromyard soil series, being fertile well-drained reddish fine silty clay loams over shale, with good water retention and moderate permeability. At the trial site at Brooke House the soil had a higher silt content than typically found in the Bromyard series, and being on level ground at the foot of the slope, was less well drained. At Foxhalls the trial site was sandier and with improved midslope drainage.

Field preparation at both sites involved ploughing, followed by cultivations to remove weeds and to make a suitable tilth. Beds were then formed, tilled and de-stoned. Prior to planting, the Brooke House field received a dressing of 10 tonnes per hectare of the manure product Bioganix (composted feathers and green waste permissible in Organic farming), supplying approximately 160 kgN/ha that season. Organic manure was not applied at Foxhalls, and neither site received any mineral fertilisers. Planting was later than intended at both sites due to wet weather in late April.

Other agronomic inputs included mechanical weeding and ridging in May and June, and prophylactic sprays of copper sulphate from June to August to protect against high disease pressure from potato blight *(Phytophthora infestans)*.

The weather conditions during June and July were essentially mild, dull and wet, similar to 2007. The Valor at Brooke House grew vigorously, but the Amarosa at Foxhalls suffered from weed competition in June and failed to complete a canopy between the rows. Crop

development suffered from cold seedbeds, a lack of sunshine, generally low temperatures and wet subsoils. Severe disease pressure forced the premature haulm removal of the Amarosa on 15th August, giving it a growing period of only 90 days. The Valor haulm was not removed until 29th August; a longer growing period of 106 days.

Experiment Method

Plots were marked out to compare six different treatments in each of four blocks or replicates. Each block consisted of six 5-metre plots laid end-to-end covering a pair of adjacent rows, or single bed 1.9m wide. Blocks were separated from each other laterally by at least 2 beds to minimise the risk of spray drift from different treatments.

The six treatments tested were as follows: -

1 Untreated control.
2 TwinN applied to bare soil at planting and to soil and foliage at full emergence.
3 TwinN applied at planting, full emergence, and at tuber initiation.
4 TwinN with AgriKelp applied at planting and at full emergence.
5 TwinN with AgriKelp applied at planting, full emergence, and at tuber initiation.
6 AgriKelp alone applied at planting, full emergence, and at tuber initiation.

At each spray application a new vial of TwinN was re-hydrated according to manufacturer's instructions, using 100mls of non-chlorinated borehole water at ambient room temperature (15 to 20°C). The Rehydration Solution was then left to stand for 4 hours prior to use in the field. The journey time to each field site was no more than 20 minutes.

Spray applications were made using a hand-operated CP3 knapsack sprayer fitted with a Hardy 'brown' low drift flat fan nozzle, operating at 3-bar pressure, and with the in-line nozzle filter removed. Prior to each application the sprayer was cleansed using the proprietary tank cleaner All Clear, and triple-rinsed with borehole water. To minimise the risk of ultra-violet radiation or desiccation damaging the TwinN organisms, the spraying was done in the evening and at the high volume spray of 600 litres per hectare. AgriKelp was applied at its recommended rate of 10 litres per hectare.

The spraying water used was local to each site; borehole water at Brooke House and pond water at Foxhalls. Water was transported the short distances to each site and treatment sprays were mixed up fresh immediately before each treatment application. For treatments 4 and 5 the AgriKelp was thoroughly mixed into the spray tank prior to adding the TwinN from the Rehydration Solution.

All spray volumes were achieved within 3% of the intended 600 l/ha, and the timings and conditions at spraying were as follows:

At planting to bare soil –

Brooke House – 20th May 2008, to moist soil, 5 days after planting; spray volume 605 l/ha; 1930 to 2045hrs in fine still cloudy and cool conditions.
Foxhalls – 21st May 2008, to moist soil, 4 days after planting; spray volume 615 l/ha; 2000 to 2130hrs in cool overcast conditions.

At full emergence –

Brooke House – 21st June 2008; to both soil and leaf; spray volume 610 l/ha;
1645 to 1800hrs amid light drizzle, and light rain after 2000hrs.
Foxhalls – 24th June 2008; to both soil and leaf; spray volume 615 l/ha;
2000 to 2115hrs, overcast and humid with light drizzle from 2100hrs.

At tuber initiation –

Brooke House – 17th July 2008; to dry leaves, spray volume 605 l/ha;
1700 to 1800hrs overcast and humid with rain from 1915hrs.
Foxhalls – 17th July 2008; to dry leaves; spray volume 610 l/ha;
1900 to 2000hrs, cool and cloudy with light drizzle from 1945hrs.

The date of tuber initiation was judged to be 17th July for the Valor at Brooke House and 21st July for the Amarosa at Foxhalls.

Harvest yields were measured by hand digging 2 metres (6 plants) in a single row; the Valor on 13th September, and the Amarosa on 11th September. Each plot of lifted potatoes was bagged and carried from the field to be cleaned, graded and weighed by hand. In this way, both a weight and count of tubers was obtained for each plot, of sizes or grades ranging from <25 to >75mm, in increments of 10mm. These were converted to yields in tonnes per hectare.

Experiment Design and Analysis

The six treatments were arranged in fully randomised complete block designs, with 4 replicates of each treatment at each site.

The results are tabled below giving the mean yields of tubers for each grade comparing treatments within each variety. The analyses of variance were performed on individual plot data using Microsoft Minitab v.13, and the tables of results report the Least Significant Difference (LSD) with $p<0.05$.

For comparing treatment means within each table, a Duncan's test is used to denote whether the differences are statistically valid, and lower case letters are placed next to each of the values. Values can be compared only to others within the same column. If any of the lower case letters adjacent to the values being compared are the same, then those values cannot be said to be statistically different from each other at the 5% level of confidence ($p<0.05$). In other words, if figures in a column share any of the lower case letters next to them, they cannot be said to be different from each other with more than 95% certainty.

Results

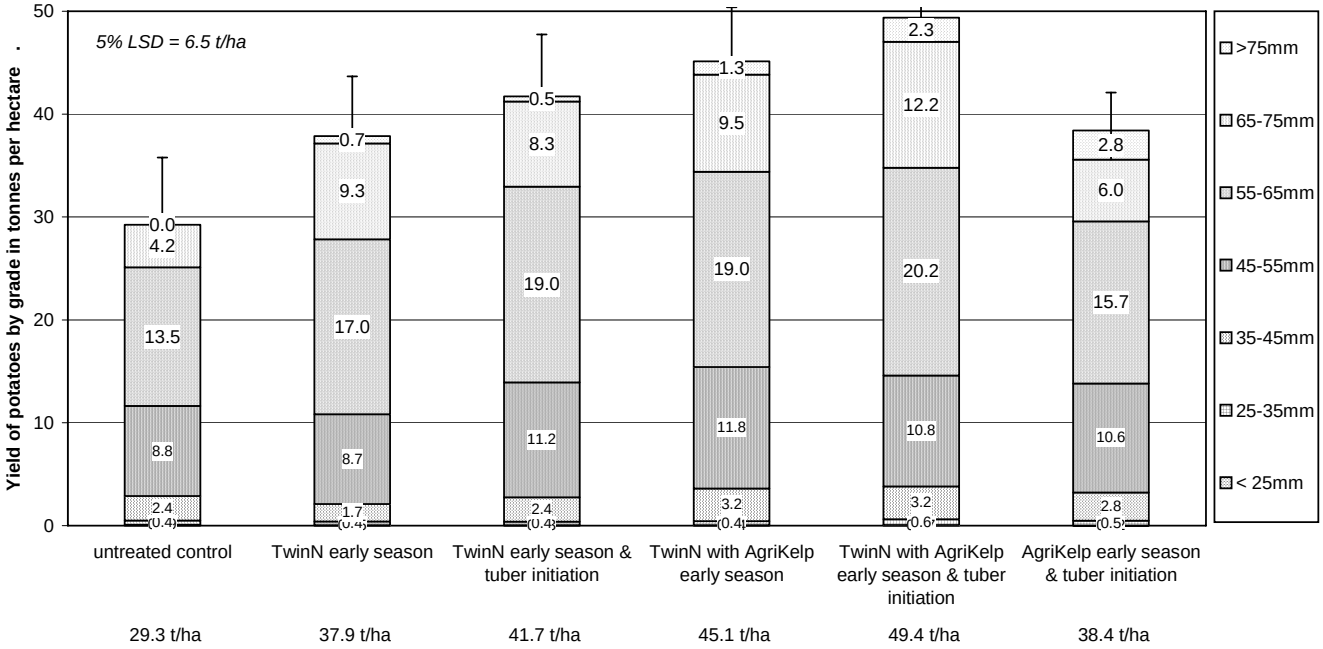
Yields of each grade, and the total yield of potatoes comparing the six treatments, for both sites, are presented below in Tables 1 and 2.

TABLE 1 - Brooke House, cv. Valor		Yield of Potatoes by grade in Tonnes per hectare							
	Treatments 2008	< 25mm	25-35mm	35-45mm	45-55mm	55-65mm	65-75mm	>75mm	Total of all grades
1	untreated control	0.09 a	0.40 a	2.4 a	8.8 a	13.5 a	4.2 a	0.0 a	29.3 a
2	TwinN applied at planting and emergence	0.05 a	0.36 a	1.7 a	8.7 a	17.0 abc	9.3 bcd	0.7 a	37.9 b
3	TwinN applied at planting, emergence and tuber initiation	0.03 a	0.35 a	2.4 a	11.2 a	19.0 bc	8.3 bc	0.5 a	41.7 bc
4	TwinN with AgriKelp applied at planting and emergence	0.04 a	0.39 a	3.2 a	11.8 a	19.0 bc	9.5 cd	1.3 a	45.1 cd
5	TwinN with AgriKelp applied at planting, emergence and tuber initiation	0.07 a	0.56 a	3.2 a	10.8 a	20.2 c	12.2 d	2.3 a	49.4 d
6	AgriKelp applied at planting, emergence and tuber initiation	0.02 a	0.46 a	2.8 a	10.6 a	15.7 ab	6.0 ab	2.8 a	38.4 b
	LSD (p<0.05)	*0.086*	*0.446*	*2.13*	*4.36*	*4.01*	*3.43*	*3.03*	*6.53*

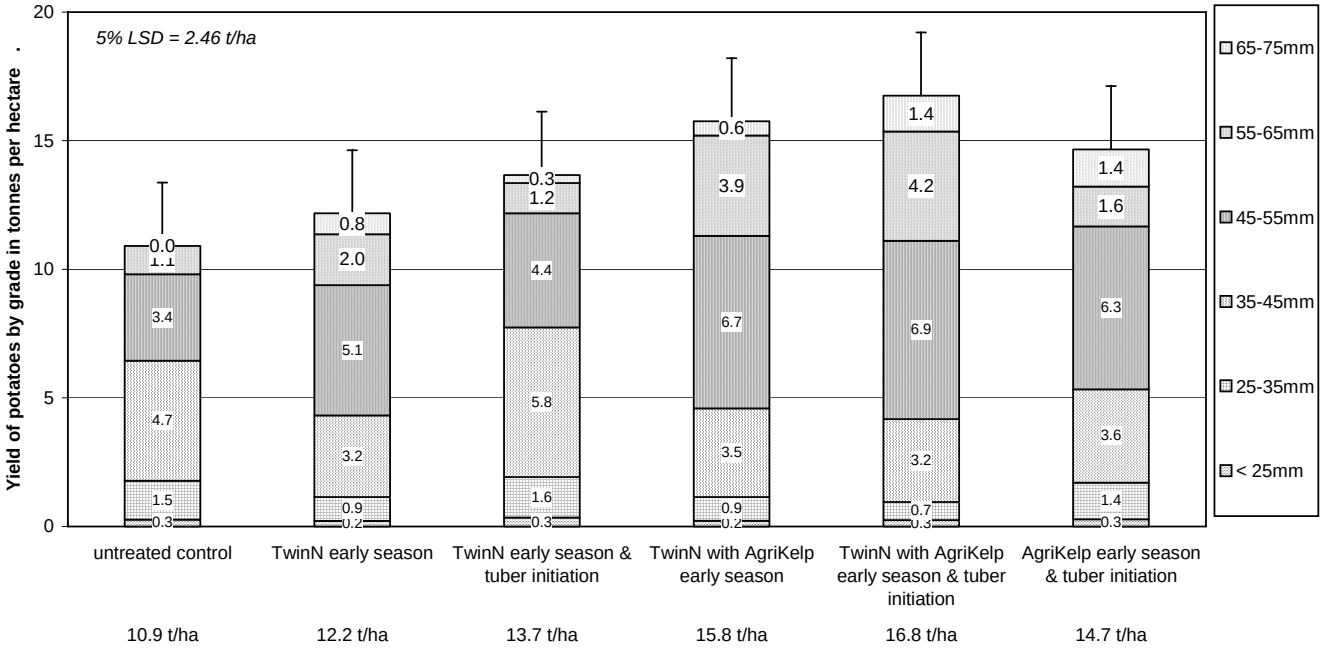
TABLE 2 - Foxhall, cv. Amarosa		Yield of Potatoes by grade in Tonnes per hectare							
	Treatments 2008	< 25mm	25-35mm	35-45mm	45-55mm	55-65mm	65-75mm	>75mm	Total of all grades
1	untreated control	0.3 a	1.5 a	4.7 ab	3.4 a	1.1 a	0.0 a	0.0 a	10.9 a
2	TwinN applied at planting and emergence	0.2 a	0.9 a	3.2 a	5.1 abc	2.0 a	0.8 a	0.0 a	12.2 ab
3	TwinN applied at planting, emergence and tuber initiation	0.3 a	1.6 a	5.8 b	4.4 ab	1.2 a	0.3 a	0.0 a	13.7 bc
4	TwinN with AgriKelp applied at planting and emergence	0.2 a	0.9 a	3.5 a	6.7 c	3.9 b	0.6 a	0.0 a	15.8 cd
5	TwinN with AgriKelp applied at planting, emergence and tuber initiation	0.3 a	0.7 a	3.2 a	6.9 c	4.2 b	1.4 a	0.0 a	16.8 d
6	AgriKelp applied at planting, emergence and tuber initiation	0.3 a	1.4 a	3.6 a	6.3 bc	1.6 a	1.4 a	0.0 a	14.7 cd
	LSD (p<0.05)	*0.24*	*0.92*	*1.95*	*1.91*	*1.88*	*1.99*	*0.00*	*2.46*

Charts of the data above are drawn below. The full height of each column represents the mean total yield for each treatment, and the T-bars on each denote their LSD at $p<0.05$.

Effect of microbial nitrogen-fixing product TwinN and biostimulant AgriKelp on yield of organic potatoes (cv. Valor) England 2008.



Effect of microbial nitrogen-fixing product TwinN and biostimulant AgriKelp on yield of organic potatoes (cv. Amarosa) England 2008.



The yields for each grade (in Tables 1&2) are expressed as percentages of the yields in the untreated controls in Tables 3 and 4 below.

TABLE 3 - Brooke House, cv. Valor		Yield of Potatoes as a percentage of the untreated control							
	Treatments 2008	< 25mm	25-35mm	35-45mm	45-55mm	55-65mm	65-75mm	>75mm	Total of all grades
1	untreated control	100% a	100% a	100% a	100% a	100% a	100% a	* a	100% a
2	TwinN applied at planting and emergence	51% a	90% a	72% a	99% a	126% abc	224% bcd	* a	129% b
3	TwinN applied at planting, emergence and tuber initiation	35% a	88% a	100% a	128% a	141% bc	199% bc	* a	143% bc
4	TwinN with AgriKelp applied at planting and emergence	38% a	97% a	135% a	135% a	141% bc	228% cd	* a	154% cd
5	TwinN with AgriKelp applied at planting, emergence and tuber initiation	73% a	139% a	134% a	123% a	150% c	295% d	* a	169% d
6	AgriKelp applied at planting, emergence and tuber initiation	19% a	114% a	116% a	121% a	117% ab	145% ab	* a	131% b
	LSD (p<0.05)	*92%*	*111%*	*90%*	*50%*	*30%*	*83%*	*	*22%*

TABLE 4 - Foxhall, cv. Amarosa		Yield of Potatoes as a percentage of the untreated control							
	Treatments 2008	< 25mm	25-35mm	35-45mm	45-55mm	55-65mm	65-75mm	>75mm	Total of all grades
1	untreated control	100% a	100% a	100% ab	100% a	100% a	* a	* a	100% a
2	TwinN applied at planting and emergence	78% a	62% a	68% a	151% abc	179% a	* a	* a	112% ab
3	TwinN applied at planting, emergence and tuber initiation	126% a	105% a	125% b	132% ab	107% a	* a	* a	126% bc
4	TwinN with AgriKelp applied at planting and emergence	82% a	61% a	74% a	199% c	354% b	* a	* a	144% cd
5	TwinN with AgriKelp applied at planting, emergence and tuber initiation	92% a	47% a	69% a	206% c	385% b	* a	* a	154% d
6	AgriKelp applied at planting, emergence and tuber initiation	102% a	95% a	77% a	188% bc	141% a	* a	* a	135% cd
	LSD (p<0.05)	*89%*	*61%*	*42%*	*57%*	*171%*	*	*	*23%*

Tables 5 and 6 below group the yields for individual grades into sizes smaller and larger than 45mm, as well as over both 55 and 65mm.

TABLE 5 - Brooke House, cv. Valor		Yield of potatoes by grade in Tonnes per hectare			
Treatments 2008		<45mm	>45mm	>55mm	>65mm
1	untreated control	2.9 a	26.4 a	17.6 a	4.2 a
2	TwinN applied at planting and emergence	2.1 a	35.8 bc	27.0 b	10.0 bc
3	TwinN applied at planting, emergence and tuber initiation	2.8 a	39.0 bc	27.8 b	8.8 ab
4	TwinN with AgriKelp applied at planting and emergence	3.6 a	41.5 cd	29.7 bc	10.7 bc
5	TwinN with AgriKelp applied at planting, emergence and tuber initiation	3.8 a	45.6 d	34.8 c	14.6 c
6	AgriKelp applied at planting, emergence and tuber initiation	3.2 a	35.2 b	24.6 b	8.8 ab
	LSD (p<0.05)	*2.48*	*5.76*	*5.24*	*5.66*

TABLE 6 - Foxhall, cv. Amarosa		Yield of potatoes by grade in tonnes per hectare			
Treatments 2008		<45mm	>45mm	>55mm	>65mm
1	untreated control	6.5 bc	4.5 a	1.1 a	0.0 a
2	TwinN applied at planting and emergence	4.3 ab	7.9 bc	2.8 abc	0.8 a
3	TwinN applied at planting, emergence and tuber initiation	7.8 c	6.0 ab	1.5 a	0.3 a
4	TwinN with AgriKelp applied at planting and emergence	4.6 ab	11.1 de	4.5 bc	0.6 a
5	TwinN with AgriKelp applied at planting, emergence and tuber initiation	4.2 a	12.6 e	5.7 c	1.4 a
6	AgriKelp applied at planting, emergence and tuber initiation	5.4 ab	9.4 cd	3.0 abc	1.5 a
	LSD (p<0.05)	*2.29*	*3.17*	*2.64*	*1.99*

And the yields of the grouped sizes are also presented as percentages of the untreated controls in Tables 7 & 8 below.

TABLE 7 - Brooke House, cv. Valor		Yield of potatoes as a percentage of the untreated control			
Treatments 2008		<45mm	>45mm	>55mm	>65mm
1	untreated control	100% a	100% a	100% a	100% a
2	TwinN applied at planting and emergence	74% a	136% bc	153% b	242% bc
3	TwinN applied at planting, emergence and tuber initiation	96% a	148% bc	158% b	211% ab
4	TwinN with AgriKelp applied at planting and emergence	126% a	157% cd	168% bc	258% bc
5	TwinN with AgriKelp applied at planting, emergence and tuber initiation	132% a	173% d	197% c	351% c
6	AgriKelp applied at planting, emergence and tuber initiation	113% a	133% b	139% b	213% ab
	LSD (p<0.05)	*86%*	*22%*	*30%*	*136%*

TABLE 8 - Foxhall, cv. Amarosa		Yield of potatoes as a percentage of the untreated control			
Treatments 2008		<45mm	>45mm	>55mm	>65mm
1	untreated control	100% bc	100% a	100% a	* a
2	TwinN applied at planting and emergence	67% ab	176% bc	255% abc	* a
3	TwinN applied at planting, emergence and tuber initiation	120% c	134% ab	136% a	* a
4	TwinN with AgriKelp applied at planting and emergence	71% ab	250% de	405% bc	* a
5	TwinN with AgriKelp applied at planting, emergence and tuber initiation	65% a	283% e	514% c	* a
6	AgriKelp applied at planting, emergence and tuber initiation	83% ab	210% cd	273% abc	* a
	LSD (p<0.05)	*35%*	*71%*	*240%*	*

Treatment effects on the vigour of the haulm were only measurable in the lower yielding Amarosa, but not until mid July. Such a late response is indicative of its tardy growth and subsequent low yield.

TABLE 9 - Foxhall - cv. Amarosa		Vigour of haulm as a percentage of the untreated control	
Treatments 2008		24-Jun	16-Jul
1	untreated control	100% a	100% a
2	TwinN applied at planting and emergence	116% a	112% ab
3	TwinN applied at planting, emergence and tuber initiation	107% a	112% ab
4	TwinN with AgriKelp applied at planting and emergence	113% a	130% bc
5	TwinN with AgriKelp applied at planting, emergence and tuber initiation	105% a	136% c
6	AgriKelp applied at planting, emergence and tuber initiation	113% a	130% bc
	LSD (p<0.05)	*17%*	*22%*

Harvest assessments included a tuber count for each grade, and these are presented in Tables 10 and 11 below as the numbers of tubers per 10 plants comparing each treatment.

TABLE 10 - Brooke House, cv. Valor		Average number of tubers per 10 plants for each grade							
	Treatments 2008	< 25mm	25-35mm	35-45mm	45-55mm	55-65mm	65-75mm	>75mm	Total of all grades
1	untreated control	4.2 a	6.3 a	13.3 a	27.9 a	22.9 a	4.6 a	0.0 a	79.2 a
2	TwinN applied at planting and emergence	2.5 a	5.4 a	10.0 a	27.1 a	28.7 ab	9.6 b	0.4 a	83.8 ab
3	TwinN applied at planting, emergence and tuber initiation	1.7 a	5.8 a	13.8 a	34.6 a	34.2 bc	10.0 b	0.4 a	100.4 abc
4	TwinN with AgriKelp applied at planting and emergence	1.7 a	6.3 a	19.2 a	38.3 a	33.8 bc	11.3 bc	0.8 a	111.3 bc
5	TwinN with AgriKelp applied at planting, emergence and tuber initiation	2.9 a	8.3 a	19.6 a	36.7 a	35.4 c	14.2 c	1.7 a	118.8 c
6	AgriKelp applied at planting, emergence and tuber initiation	1.3 a	7.1 a	16.7 a	35.0 a	27.9 ab	5.8 a	2.1 a	95.8 abc
	LSD (p<0.05)	*4.07*	*5.99*	*11.86*	*14.52*	*6.67*	*3.71*	*2.16*	*28.59*

TABLE 11 - Foxhall, cv. Amarosa		Average number of tubers per 10 plants for each grade							
	Treatments 2008	< 25mm	25-35mm	35-45mm	45-55mm	55-65mm	65-75mm	>75mm	Total of all grades
1	untreated control	17.8 a	19.5 a	26.3 ab	10.5 a	2.5 a	0.0 a	0.0 a	76.8 ab
2	TwinN applied at planting and emergence	13.8 a	13.0 a	19.5 a	16.0 ab	4.3 ab	0.8 a	0.0 a	67.5 a
3	TwinN applied at planting, emergence and tuber initiation	17.5 a	20.5 a	34.8 b	14.5 a	2.5 a	0.5 a	0.0 a	90.3 b
4	TwinN with AgriKelp applied at planting and emergence	12.3 a	13.3 a	21.5 a	24.0 c	8.0 bc	0.5 a	0.0 a	80.0 ab
5	TwinN with AgriKelp applied at planting, emergence and tuber initiation	10.8 a	11.8 a	22.0 a	23.3 c	9.8 c	1.3 a	0.0 a	78.8 ab
6	AgriKelp applied at planting, emergence and tuber initiation	14.5 a	23.5 a	22.8 a	20.8 *bc*	3.5 a	1.5 a	0.0 a	86.8 ab
	LSD (p<0.05)	*9.95*	*13.21*	*11.56*	*6.30*	*3.87*	*1.91*	*0.00*	*22.25*

And again, the treatment means above are presented as percentages of the untreated control in Tables 12 and 13 below.

TABLE 12 - Brooke House, cv. Valor		Number of tubers as a percentage of the untreated control							
	Treatments 2008	< 25mm	25-35mm	35-45mm	45-55mm	55-65mm	65-75mm	>75mm	Total of all grades
1	untreated control	100% a	100% a	100% a	100% a	100% a	100% a	* a	100% a
2	TwinN applied at planting and emergence	60% a	87% a	75% a	97% a	125% ab	209% b	* a	106% ab
3	TwinN applied at planting, emergence and tuber initiation	40% a	93% a	103% a	124% a	149% bc	218% b	* a	127% abc
4	TwinN with AgriKelp applied at planting and emergence	40% a	100% a	144% a	137% a	147% bc	245% bc	* a	141% bc
5	TwinN with AgriKelp applied at planting, emergence and tuber initiation	70% a	133% a	147% a	131% a	155% c	309% c	* a	150% c
6	AgriKelp applied at planting, emergence and tuber initiation	30% a	113% a	125% a	125% a	122% ab	127% a	* a	121% abc
	LSD (p<0.05)	*98%*	*96%*	*89%*	*52%*	*29%*	*81%*	*	*36%*

TABLE 13 - Foxhall, cv. Amarosa		Number of tubers as a percentage of the untreated control							
	Treatments 2008	< 25mm	25-35mm	35-45mm	45-55mm	55-65mm	65-75mm	>75mm	Total of all grades
1	untreated control	100% a	100% a	100% ab	100% a	100% a	* a	* a	100% ab
2	TwinN applied at planting and emergence	77% a	67% a	74% a	152% ab	170% ab	* a	* a	88% a
3	TwinN applied at planting, emergence and tuber initiation	99% a	105% a	132% b	138% a	100% a	* a	* a	118% b
4	TwinN with AgriKelp applied at planting and emergence	69% a	68% a	82% a	229% c	320% bc	* a	* a	104% ab
5	TwinN with AgriKelp applied at planting, emergence and tuber initiation	61% a	60% a	84% a	221% c	390% c	* a	* a	103% ab
6	AgriKelp applied at planting, emergence and tuber initiation	82% a	121% a	87% a	198% *bc*	140% a	* a	* a	113% ab
	LSD (p<0.05)	*56%*	*68%*	*44%*	*60%*	*155%*	*	*	*29%*

Tables 14 and 15 show the numbers of tubers per 10 plants for groups of sizes smaller and larger than 45mm, as well as over both 55 and 65mm.

TABLE 14 - Brooke House, cv. Valor		Average number of tubers per 10 plants by grade			
Treatments 2008		<45mm	>45mm	>55mm	>65mm
1	untreated control	23.8 a	55.4 a	27.5 a	4.6 a
2	TwinN applied at planting and emergence	18.0 a	65.8 ab	38.8 bc	10.0 b
3	TwinN applied at planting, emergence and tuber initiation	21.3 a	79.2 bcd	44.6 cd	10.4 b
4	TwinN with AgriKelp applied at planting and emergence	27.1 a	84.2 cd	45.9 cd	12.1 bc
5	TwinN with AgriKelp applied at planting, emergence and tuber initiation	30.8 a	87.9 d	51.3 d	15.8 c
6	AgriKelp applied at planting, emergence and tuber initiation	25.0 a	70.9 abc	35.8 b	7.9 ab
	LSD (p<0.05)	*17.64*	*16.71*	*7.44*	*5.04*

TABLE 15 - Foxhall, cv. Amarosa		Average number of tubers per 10 plants by grade			
Treatments 2008		<45mm	>45mm	>55mm	>65mm
1	untreated control	63.8 ab	12.9 a	2.5 a	0.0 a
2	TwinN applied at planting and emergence	46.2 a	21.2 bc	5.0 ab	0.8 a
3	TwinN applied at planting, emergence and tuber initiation	72.6 b	17.5 ab	2.9 a	0.4 a
4	TwinN with AgriKelp applied at planting and emergence	47.6 a	32.6 de	8.3 bc	0.4 a
5	TwinN with AgriKelp applied at planting, emergence and tuber initiation	44.5 a	34.1 e	10.9 c	1.3 a
6	AgriKelp applied at planting, emergence and tuber initiation	60.8 ab	25.8 cd	5.0 ab	1.6 a
	LSD (p<0.05)	*24.99*	*7.55*	*4.42*	*1.91*

Tables 16 and 17 below show the tuber counts for grouped sizes as percentages of the untreated control.

TABLE 16 - Brooke House, cv. Valor		Number of tubers as a percentage of the untreated control			
Treatments 2008		<45mm	>45mm	>55mm	>65mm
1	untreated control	100% a	100% a	100% a	100% a
2	TwinN applied at planting and emergence	75% a	119% ab	141% bc	219% b
3	TwinN applied at planting, emergence and tuber initiation	89% a	143% bcd	162% cd	227% b
4	TwinN with AgriKelp applied at planting and emergence	114% a	152% cd	167% cd	264% bc
5	TwinN with AgriKelp applied at planting, emergence and tuber initiation	130% a	159% d	186% d	346% c
6	AgriKelp applied at planting, emergence and tuber initiation	105% a	128% abc	130% b	173% ab
	LSD (p<0.05)	*74%*	*30%*	*27%*	*110%*

TABLE 17 - Foxhall, cv. Amarosa		Number of tubers as a percentage of the untreated control			
Treatments 2008		<45mm	>45mm	>55mm	>65mm
1	untreated control	100% ab	100% a	100% a	* a
2	TwinN applied at planting and emergence	72% a	164% bc	200% ab	* a
3	TwinN applied at planting, emergence and tuber initiation	114% b	136% ab	116% a	* a
4	TwinN with AgriKelp applied at planting and emergence	75% a	252% de	330% bc	* a
5	TwinN with AgriKelp applied at planting, emergence and tuber initiation	70% a	264% e	434% c	* a
6	AgriKelp applied at planting, emergence and tuber initiation	95% ab	199% cd	200% ab	* a
	LSD (p<0.05)	*39%*	*58%*	*177%*	*

Conclusions

1. For potatoes grown under organic regimes, and planted late (mid May), the yield of Valor at Brooke House was average at 30 t/ha, although higher than expected, and the yield of Amarosa at Foxhalls was low at 11 t/ha.

2. Both of these field experiments gave clear significant yield responses to all the TwinN and AgriKelp treatments tested. The yield increases were all indicative of increased nitrogen availability.

3. TwinN applied alone [treatment 2], to the bare soil a few days after planting in mid May, and repeated at full emergence, gave a significant yield increase of 8 t/ha (29%) for Valor, [Tables 1&3]. Although the apparent increase in total yield of 1 t/ha in the Amarosa was not significant at $p<0.05$ [Table 1], the yield of tubers over 45mm was, with an increase of over 3 t/ha (76%), [Tables 6&8].

4. An additional application of TwinN at tuber initiation [treatment 3] appeared to increase yields further, but this was not quite significant at $p<0.05$, despite being a 14% in both varieties, [Tables 3&4]. However, compared to the untreated control, this course of three applications of TwinN gave a significant yield increase of 7 t/ha (43%) for Valor, and over 2 t/ha (26%) of Amarosa.

5. Adding AgriKelp to the spray tank, before mixing in the TwinN, [treatment 4] improved the yield of Valor by a further 7 t/ha (25%), amounting to a 15 t/ha (54%) increase over the untreated control! Adding the AgriKelp to the early season sprays of TwinN, also gave a significant yield increase in the Amarosa of 3 t/ha (32%). This was almost 5 t/ha (44%) more than the untreated control.

6. Applying AgriKelp with the TwinN in a course of three sprays, at planting, full emergence and at tuber initiation [treatment 5], appeared to give the highest yields at both sites, more than 49 t/ha of Valor and approaching 17 t/ha of Amarosa. However, this third spray did not add significantly to the yield increase from the two earlier sprays [treatment 4], but it demonstrated clearer yield improvements over the lower yielding treatments.

7. In the Amarosa, between 4 and 8 t/ha were graded under 45mm, but in the Valor this was a more commercially acceptable 2 to 3 t/ha [Tables 5&6]. Excepting one anomaly, all the yield increases described above were in fact measured in the larger tubers: between 45 & 65mm for the Amarosa and 55 to 75mm in the Valor [Table 1]. This demonstrates that both TwinN and AgriKelp actively increased the availability of nitrogen in the crop.

8. The yield increases from the treatments seem proportionally higher when the smaller tubers are ignored, and only the larger ones are considered. For instance, the yield of tubers over 45mm was shown to be almost doubled in the Valor, and more than doubled in the Amarosa, from either two or three sprays of TwinN with AgriKelp.

9. The sprays applied at tuber initiation appeared to have given small yield increases but none of these was significant. The majority of the treatment effects were seen from the earlier applications as might be expected of increases in available nitrogen.

10. Despite the varieties yielding very differently, the yield increases from the treatments were proportionally very similar in both.

11. Applications of TwinN normally cost £25-/ha per application, but the higher rates used here cost under £65-/ha. Nevertheless, this higher cost was more than justified, with the three applications costing less than £190- returning over 12 tonnes of organic Valor potatoes worth nearly £4,000-.

Acknowledgements

The assistance of DF & SL Watts (Little Frome Farm, Avenbury, with whom this crop was grown in partnership with Agrimarc Ltd), and P Rogers & Son (Foxhalls Farm, Sollers Hope) are both gratefully acknowledged.
