BIOMASS AND BIOENERGY 68 (2014) 185–194

Available online at www.sciencedirect.com

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The yield and quality response of the energy grass *Miscanthus* × *giganteus* to fertiliser applications of nitrogen, potassium and sulphur

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ARTICLE INFO

Article history:
Received 3 March 2014
Received in revised form
6 June 2014
Accepted 10 June 2014
Available online

Keywords:
Miscanthus
Fertiliser
Yield
Quality
Financial and energy budget

ABSTRACT

A field experiment was conducted with the energy crop *Miscanthus* × *giganteus* to investigate the effects of N, K and S fertilisers. Planted in 2003 on a sandy loam soil, treatments were applied and yield and quality measured during 2005–2007.

Soil Mineral N (SMN) in spring was between 30 and 40 kg ha^{-1} N. The optimum N application for yield was 100 kg ha^{-1} N, which increased mean gross margin by £132 ha^{-1} and yield by 3.9 t ha^{-1} DM to 13.5 (+/− 0.46) t ha^{-1} DM compared to zero applied N. Increasing the rate of application of N increased the concentration of N, K and Cl in the harvested crop. The background K and S supply was adequate for maximum crop yield. Adding 50 kg ha^{-1} K as KCl was shown to be the most appropriate way to apply maintenance dressings with minimal effect on harvested crop K and Cl concentrations. In 2008–09 a uniform application of 100 kg ha^{-1} N was made over the whole site; there were no yield effects due to the previous differential applications (mean = 12.85 t ha^{-1} DM).

The work demonstrates the need to take into account all sources of N when considering N applications to miscanthus. On this relatively poor nutrient retention soil the use of N fertiliser is clearly justified in financial terms. The use of N and K fertilisers for maximum yield needs to be balanced against crop quality affects.

1. Introduction

The desire to combat continuing climate change, and in certain sectors to achieve greater national/regional energy security, has resulted in much increased interest in renewable energy technologies [1]. A major contributor already, and with much future potential, bio-energy features strongly in the research and commercial sectors. Non-food crops planted specifically for the energy sector provide a sustainable bio-energy option. Of these, miscanthus (*Miscanthus* × *giganteus*) and short rotation coppice willow (*Salix* spp.) are most commonly used in the UK at the present time.

The sustainability and financial profitability of energy crops is influenced strongly by the need for nitrogen fertiliser. Nitrogen fertiliser constitutes an expensive input used in large quantities in the production of many agricultural crops and is also a major cause of GHG emissions from agriculture. The optimal use of N fertiliser in the miscanthus crop is a controversial subject. A recent review by Cadoux et al. [2]

abbreviations: DM, dry matter; GHG, green house gas; SMN, soil mineral nitrogen; SNS, soil nitrogen supply.

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http://dx.doi.org/10.1016/j.biombioe.2014.06.007

showed that out of 11 studies on the yield response of *Miscanthus × giganteus* to N fertiliser, 6 reported a positive yield response but 5 reported no response. The authors' own work over 14 years [3] showed no response to applications of 60 or 120 kg ha^{-1} N (compared to 0), and has been widely quoted as demonstrating that the crop requires no additional N input for maximum yield, this has even been specifically mentioned in the Natural England Growers Guide for miscanthus [4].

Soil Mineral Nitrogen (SMN) is a snapshot of available N in the soil (NO_3 and NH_4) that is readily available to a plant, as distinct from the N applied as fertiliser. SMN is considered the best indicator of Soil Nitrogen Supply (SNS = SMN + mineralisation) as mineralisation approximately replaces the SMN not captured by the crop (and therefore potentially lost from the soil plant system) during spring and summer in most mineral soils [5]. Closer examination of the published work shows that of the 5 papers reporting no response to applied N some directly quote large SMN supplies of up to 380 kg ha^{-1} N [6]. Christian et al. [3] hypothesise that the SNS supply was large due to the cropping history in which a medium term grass ley had been ploughed shortly prior to planting miscanthus. The remaining three reports of no response to applied N [7–9] include very high yields and high crop N content suggesting abundant SMN supplies.

Of those reporting responses to applied N, two involved large increases in yield but also very high absolute yields in association with irrigation in southern European conditions [10,11]. In at least one case [12] the researchers suspected that they may have been recording a response to the K component of the NPK fertiliser application (72 kg ha^{-1} yr^{-1} K) in conditions of soil K deficiency (maximum of 39 mg kg topsoil^{-1} K). Boehmel et al. [13] measured <40 kg ha^{-1} SMN and then recorded a significant increase in yield from an application of 40 kg ha^{-1} N, but no further increase from adding 80 kg ha^{-1} N. The work of Lewandowski et al. [14] is particularly valuable as it uses a large number of data points derived from 4 sites of different soil type in SW Germany and accounts for SMN in addition to applied N. However, yields were taken from an area of only 1 m^2. They used the Boundary Line Approach to show a strong response to total N supplies up to 50 kg ha^{-1} N, a small asymptote and then a decline in yield at an N supply greater than 114 kg ha $^{-1}$ N. Acaroglu and Aksoy [15] recorded no significant effects of N application in years 1 and 2 of the crop life but significant response to 50 and 100 kg ha^{-1} N in year 3, when they also observed a decline in yield where 150 and 200 kg ha^{-1} N were applied.

Boehmel et al. [13] and Lewandowski et al. [14] stress the importance of nitrogen fertiliser applications in GHG and energy balances for energy crops. Lewandowski et al. [14] quite rightly highlight that this does not necessarily mean that N fertiliser should not be applied. In conditions where crop yield increases may be expected from application that mitigate greater quantities of GHGs or capture greater quantities of energy than are expended in manufacturing and distributing the fertiliser, the application is justified and sustainable [16].

In order to contribute to energy demands, whilst also supplying food from the land, the efficiency of production of bio-energy from every unit of land area needs to be maximised within sustainability criteria. Therefore data contributing to decision making regarding crop management, and fertiliser application in particular, are vital.

The work reported here was designed to look simultaneously at crop yield and quality responses to N, K and S fertilisation. As far as can be ascertained no previous work has looked at K and S fertilisation of miscanthus directly and those quoted above did not generally take into account the effects of fertiliser application upon fuel quality.

2. Methods

2.1. Experimental site and management

The experiment was conducted at the Woburn Experimental Farm in Bedfordshire, UK (52 01° N, 00 36° W, *ca.* 100 m AOD), a site of Rothamsted Research. During the period 22nd to 25th April 2003 rhizomes of *Miscanthus × giganteus* were lifted from an existing area of crop on the farm, graded by hand and used to plant an area of approximately 1 ha in Stackyard field. The experiment was placed within this block and no paths cut until final harvest each year to minimise edge effects on the plots. The planting density was 3.5 rhizome pieces (of approximately 25 g fresh weight) per m^2. The soils in this part of Stackyard field have been described as approximately equal areas of Cottenham and Stackyard Series [17]. Both soil series are sandy loams, Cottenham generally having the greater sand (>63 μm) content and lesser clay (<2 μm) content in the upper horizons (Table 1). The field has a long history of arable cropping since incorporation into the Experimental Farm in 1876. In 2001 and 2002 winter rye was grown on the miscanthus site. The only pesticides applied during the life of the experiment were metsulfuron-methyl (4 g ha^{-1} a.i., June 2003) and clopyralid (300 g ha^{-1} a.i., June 2005) for broad leafed weed control and atrazine (1.5 kg ha^{-1} a.i., with oil, March 2004) for general weed control. Soil P was considered adequate for general plant growth (05). No N, K or S fertilisers were used on the miscanthus crop prior to the first treatments being applied.

Table 1 – Particle size analysis from profiles of the two soil series present on the experimental site. Weight percentages of oven dry, decalcified and peroxidised soil. Adapted from Catt et al. (1980).

Size fractions		Cottenham			Stackyard			
		Horizon depth mm			Horizon depth mm			
		0–220	340–700	700–870	0–170	40–730	920–1120	1440–1800
63–2000 μm	Sand	70.8	84.5	91.3	68.4	64.8	92.2	90.5
2–63 μm	Silt	17.6	9.5	3.2	18.2	22.8	2.4	1.9
<2 μm	Clay	11.6	6.0	5.5	13.4	12.4	5.4	7.6