DELTA YIELD VERSUS YIELD GOAL FOR ESTIMATING SUNFLOWER NITROGEN FERTILIZATION RATES IN SOUTH AFRICA

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Abstract

Sunflower nitrogen fertilization recommendations in South Africa are based on yield goals. In this approach, soil nitrogen supply is not taken into account with the result that nitrogen fertilization recommendations from different institutions are in disagreement. Delta yield, the difference between a well fertilized crop and a zero nitrogen fertilized control, was found to be a more reliable indicator of the economic optimum nitrogen rate for maize than the yield goal, in three different countries. In seeking improved accuracy, this study was done with the aim to compare delta yield with yield goal as estimators of the economical optimum nitrogen fertilization rate for sunflower. Reported results of fifty fertilization trials, each representing a specific year and locality, were collected, the nitrogen response curves fitted and the optimum nitrogen rates, corresponding yields and delta yields calculated. Grain yield responded to applied nitrogen significantly at only twenty-five of these trials and with the calculated optimum nitrogen rate within the limits of the applied nitrogen. Only 27% of the variation in the optimum nitrogen fertilization rate was explained by yield goal compared to 87% by delta yield, making it a far more reliable indicator of the optimum nitrogen rate. The relationship between delta yield and the optimum nitrogen rate is best described by a power function: $Y = X^{0.669}$ with Y the optimum nitrogen rate and X the delta yield, both measured in kg per ha.

Introduction

In South Africa, Sunflower is mainly dryland grown on the semi-arid Highveld plateau with an elevation between 1200 and 1750 m and with an annual rainfall varying from 470 mm in the west to 750 mm in the east. The soil is predominantly of sandy texture and low in carbon content (<1%). Mean national sunflower yields vary between 900 and 1300 kg per ha annually. Rainfall is erratic in amount and timing, which, in combination with soil variability, can result in yields varying from zero to 3000 kg per ha on individual fields.

Sunflower nitrogen fertilization recommendations in South Africa are based on yield goals. These recommendations were derived from the relationship found between the yield and economically optimum fertilizer rate needed to obtain it in various field trials done before

1980. As soil nitrogen supply is not thoroughly taken into account in this approach, recommendations are vague and different sources are in disagreement.

The Fertilizer Society of South Africa (FSSA, 2002) for instance, recommends 54 kg nitrogen per ha for a yield goal of 2000 kg per ha without taking any soil property into account. The ARC-Grain Crops Institute (1999) on the other hand, recommends 60 to 70 kg nitrogen per ha on sandy and loamy soils, and 40 to 50 kg nitrogen per ha on clayey soils with no adjustment of the fertilizer rate for any other variables such as cropping history.

The sunflower crop's nitrogen requirement is 47 kg per ha, per Mg grain (Ruffo, García, Bollero, Fabrizzi & Ruiz, 2003), which, is high when compared to the 27 kg per ha per Mg grain of maize (FSSA, 2002). Despite this relatively high nitrogen requirement, past experience has shown that grain yield often does not respond to nitrogen fertilization. As nitrogen fertilization of sunflower is a standard practice amongst farmers, over application of nitrogen is probably a common feature. This state of affairs is not to the financial advantage of sunflower farmers or to the conservation of the environment.

In an attempt to deal with field scale variability in fertilization management, Kachanoski, Halloran, Aspinall & Von Bertoldi (1996) found delta yield to be a reasonably predictive index of the most economic rate of fertilizer nitrogen for maize in southern Ontario, Canada. Delta yield is defined as the increase in yield brought about by the application of fertilizer nitrogen (Delta yield = yield at economic optimum – yield at zero fertiliser nitrogen). Both Lory & Scharf (2003) and Nel & Bloem (2006) found delta yield to be a more reliable indicator of the economic optimum nitrogen rate for maize than the target yield, in five states of the USA and South Africa respectively.

Due to the potential improvement in accuracy of the delta yield procedure and the fact that its utility was never before investigated for sunflower fertilization, this study was done with the aim to compare it with the current yield goal way of estimating the economically optimum N rate using data from sunflower fertilizer trials conducted in South Africa.

Materials and method

Results of South African sunflower fertilization trials were collected from various sources. If yield response curves were not reported, regression analyses between yield and N fertilization rates were done for each site and season using a quadratic model ($Y = c + bN + aN^2$). Optimum yields; optimum nitrogen rates and delta yields were calculated from these equations using a fertilizer to grain price ratio of 3.5 on an equal mass base.

Certain criteria were used for the selection of suitable results for this study. Firstly, that grain yield significantly responded to the applied nitrogen rates and a curve could be fit with no other nutrients or other obvious factor limiting the yield. Secondly, that the optimum nitrogen rate is within the range of application rates. Thirdly, that a zero nitrogen rate or a rate relatively close to zero was part of the treatments as to be able to estimate the zero nitrogen yield. Of the 50 site and year combinations available, only 25 fulfilled these criteria and are listed in Table 1. Most of the rejected data were due to a lack of a significant yield response to applied nitrogen.

In order to compare the yield goal procedure with the delta yield procedure regression analyses were done. Optimum nitrogen rates were linearly related to optimum yields. Non-linear regression analyses were used to relate optimum nitrogen rates to delta yields with the curve forced through the origin. The best fit was obtained with a power function ($Y = X^a$).

Table 1 Data source, location, soil texture and number of curves fitted

Source	Locality	Soil texture	Dryland/Irri-gated	No. of curves
Bazelet, Dijkhuis & Esisenberg (1981)	Babsfontein	Sandy loam	D	1
Blamey & Capman (1981)	Dundee	Fine sandy clay	D	4
Loubser, Grimbeek & Bronkhorst (1988)	Vermaas	Unknown	D	3
Loubser (1991)	Sandvet	Sandy loam	I	1
Möhr (1974)	Ottosdal Potchefstroom	Sandy loam Sandy clay loam	D D	1 1
Möhr (1975)	Bothaville Coligny Gerdau Hoopstad Leeudoringstad Potchefstroom	Loamy sand Coarse sandy loam Coarse sandy loam Loamy sand Fine sandy loam Coarse sandy loam	D D D D D D	1 1 1 1 1 1
Möhr (1977)	Ottosdal Potchefstroom Coligny	Coarse sand Sandy clay loam Coarse sandy loam	D D D	1 1 1
Nel, Loubser & Hammes (2000)	Potchefstroom	Sandy clay loam	I	1
Van Vuuren (pers comm.)	Lichtenburg	Sandy loam	D	1
Oberholzer (1995)	Heilbron	Clay	D	2

Results and Discussion

Calculated optimum yields varied from 497 to 4048 kg per ha. This variation in optimum yields represents the yields encountered in South African dryland and irrigated commercial fields well. Delta yields on the other hand varied from as low as 17 to 1322 kg per ha. The calculated optimum nitrogen rates varied from 5 to 129 kg per ha. This range of optimum nitrogen rates is much wider than the recommended ranges of the two South African sources (ARC-Grain Crops Institute, 1999; FSSA, 2002).

The relationship between the optimum N fertilization rate and the optimum yield, which is the basis for the yield goal procedure, is shown in Figure 1. Only 27% of the variation in the optimum N rate is explained by yield, most likely due to the lack for accounting for the soil nitrogen supply and the uptake efficiency. The low coefficient of determination put the functional value of this method for nitrogen requirement estimation, under doubt.

The relationship between the optimum nitrogen rate and delta yield is shown in Figure 2. The coefficient of determination is 87%, about four times that of the yield goal method. Estimation of the nitrogen fertilization requirement from delta yield can therefore be considered substantially more accurate than that of the traditional yield goal method.

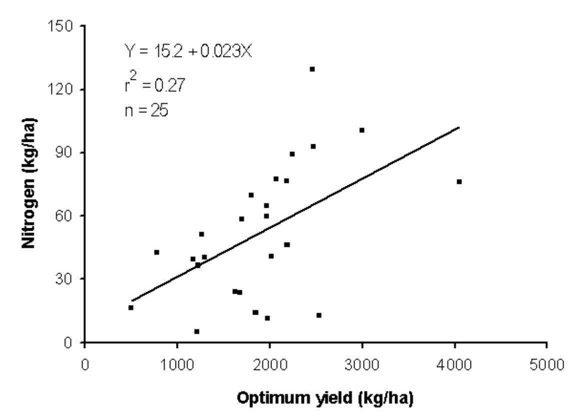

Figure 1 The relationship between optimum nitrogen rate and optimum yield.

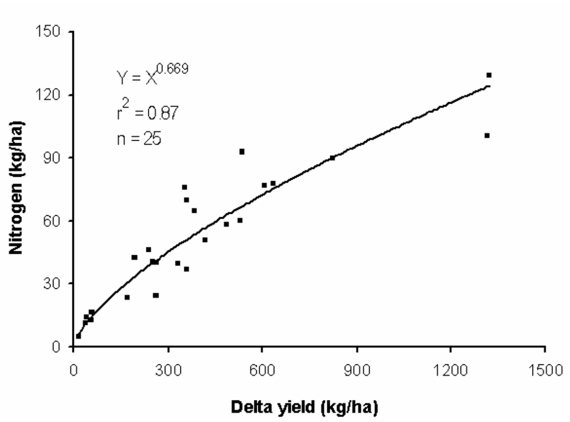

Figure 2 The relationship between optimum nitrogen rate and delta yield.

Variation is still present around the mean. Firstly, it is due to experimental error and the assumption that the yield response from all localities follows a quadratic response. Secondly, it is also due to variation of the uptake efficiency of fertilizer nitrogen. Estimates and measurements of the uptake efficiency vary from 51% (Scheiner, Guttiérrez-Boem & Lavado, 2003) to 80% (Loubser & Human, 1992; Reau, Champolivier, Sauzet, Ségura & Wagner, 2004). As it is known that grain yield is often affected by interactions between nitrogen and other nutrients, undetected limitations of other elements that affect the nitrogen use efficiency might have also be present in some of the trials used in this study.

The advantages of the delta yield procedure are pointed out by Nel & Bloem (2006). Firstly is that the delta yield procedure gives an integrated account of the soil nitrogen supply and its uptake efficiency. This eliminates possible errors with soil sampling, analysis and parameters such as the uptake efficiency that is applied with the nitrogen balance approach (Ruffo *et al.*, 2003).

A second possible advantage is that the relationship between the optimum fertilizer nitrogen rate and delta yield is not environmentally specific. In the case of maize it appears to be universal (Nel & Bloem, 2006). The wide applicability for sunflower should however be confirmed as well as the stability of the delta yield value for a particular soil and cropping system over time.

Some practical advantages also exist. The delta yield procedure is most probably less time consuming and cheaper than taking soil samples needed for the nitrogen balance approach. The whole procedure can be automated with variable fertiliser applicators and yield-monitoring combine harvesters. It is recommended by Lory & Scharf (2003) that patches or strips covering 1.62% of a maize field (648 square m for each 4 ha) should be allocated for a zero nitrogen control. The loss of income from these control plots will probably be far less than the advantage of the improved accuracy of nitrogen fertilization in most cases.

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