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Different Rates of Urea as Nitrogen Fertilizer Affect Root and Stalk Rot Diseases of Maize in South West Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Authors MOA and SOO designed the study. Author SOO wrote the protocol, authors MOA and AKN carried out the experiments. Authors MOA and AKN wrote the first draft of the manuscript. Authors MOA and SOO analyzed the data while author AKN managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aside from increasing the yield of crops, it is well known that application of fertilizers, especially Nitrogen, to soil has many other positive and negative effects. One of such effects include increasing or decreasing disease expression and/or severity. Information about the effect of continuous application of Nitrogen fertilizers to important cereals such as maize, in areas where local farmers have low access to information and technology, might go a long way in helping stakeholders to manage diseases. Two commonly cultivated maize cultivars, DMRE–Y and DMR–LSR-W, were planted in a randomized complete block design, first in Abeokuta (early cropping season of year 2000) and then in Ago-Iwoye (early cropping season of year 2001) to evaluate the effect of increasing rates of Nitrogen fertilizer (in form of urea) application on stalk rot disease

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caused by *Macrophomina phaseolina* and root rot disease caused by *Fusarium moniliforme*.
Increasing rate of Nitrogen application led to a significant increase in the severity of these diseases with the highest disease expression at 300 kg N ha^{-1}. Although the reactions of the two cultivars were similar, DMRE-Y was found to be more susceptible to these rots than DMR-LSR-W. Simple linear regression analysis indicated a very strong positive relationship between N rates and average disease index. A two year pooled index for DMRE-Y cultivar gave correlation coefficient values 0.9997 and 0.9844 for stalk and root rots respectively while for DMR-LSR-W cultivars, the values were 0.9933 and 0.9815 for stalk and root rots respectively.
Increasing rates of urea increased the grain yield but had diverse effects on yield components. The rates had no effect on plant height and ear length but considerably increased the kernel row and kernel weight. It, however, reduced days to 50% tasseling of maize crops.

Keywords: Zea mays spp; urea; nitrogen fertilizer; root rot; stalk rot; Nigeria.

1. INTRODUCTION

Maize among the cereals is the third most important crop produced in the world following wheat and rice [1-4]. The crop is a source of staple human food in Nigeria and may be prepared in various ways for consumption [5]. It also constitutes an essential ingredient in the formulation of livestock feeds due to its high energy value, low fibre content and easy digestibility. In Africa, particularly Nigeria, yield and overall production level of the crop is limited by many factors such as climate, type of varieties grown, soil type (nutrient availability), restricted inputs, diseases and pests [6]. To basically have a higher yield, most farmers apply nitrogen (N) fertilizer. Some research works recommended a N fertilizer rate of 120 Kg ha^{-1} for increasing maize yield in Southwestern [7] and 80 Kg N ha^{-1} in the Southeastern [8] part of Nigeria. However, available evidence has shown that there is a relationship between the form and quantity of N supplied to plants as well as the expression and severity of some diseases [9]. It was reported that in winter wheat, increasing N supply enhances both canopy development and powdery mildew (*Blumeria graminis*) due to effects on epidemiological parameters and canopy microclimate [10]. However, for septoria leaf spot (*Septoria tritici*) and leaf blotch *(Stagonospora nodorum*) of wheat, increases as well as decreases in disease severity have been observed at higher N rates [11,12]. The contrasting results may be due to opposing effects of canopy density on infection conditions, spore dispersal and possibly plant physiological pre-disposition to the two diseases [13]. By increasing growth, nitrogen gives a denser crop and therefore a humid environment for pathogens infection [14]. It has also been observed that the number of successful infections, colony growth rate and spore production in some pathogens also increased with increased N nutrition [14,15]. Apart from the quantity, the modes of N fertilizer applied also have pronounced effects on disease expression and severity. It was noted a reduced patch of *Rhizoctonia solani* number and severity with application of both ammonium sulphate and urea on wheat [16]. It was reported that maize plants fertilized with composted cattle manure displayed the lowest levels of gray leaf spot followed by poultry manure [17]. Other research has shown no effect of fertilizer on wheat growth [18] or patch disease incidence [19]. *Fusarium moniliforme* stalk rot is reduced by nitrate but a marked increase in stalk rot of highly susceptible sweet corn line occurred after fertilization with ammonium compared to nitrate [20].

An exclusive probe into effect of N was carried out by using six levels (0 to 150 Kg ha^{-1}) of N and it was found that with increase in N level, the disease severity was increased [21]. Other researchers tested different N levels (0, 100 and 200 Kg ha^{-1}) against *H. maydis*. They found that 100 Kg ha^{-1} was more effective in reducing disease severity and increasing yield [22].

Despite the knowledge about the relationship between fertilizer application and diseases expression, fertilizer application is only adopted by farmers in Nigeria to increase their crop yield but little information is available on the effect of this applied fertilizer on the incidence and severity of diseases of maize. Nevertheless, knowledge of host nutrition in relation to disease development provides a basis for modifying current agricultural practices to reduce disease severity.

This research was undertaken to determine the relationship between different N rates on the incidence and severity of root rot disease of maize caused by *Fusarium moniliforme* and stalk rot caused by *Macropholina phaseolina.* The aim was also to determine the optimal N rate which would minimize disease without compromising the crop's yield potential.

2. MATERIALS AND METHODS

Field experiments were carried out at two different experimental locations in south western part of Nigeria; one at University of Agriculture, Abeokuta (Lat 7°N and Long 3°23' East) and the other at Olabisi Onabanjo University Teaching and Research Farm, Ago-Iwoye (Lat 6°55'W and Long 3°45'E) during the early planting seasons (March to July) of year 2000 and 2001 respectively. The experiments were conducted alternatively at the two locations, that is, first at Abeokuta (year 2000) and then at Ago-Iwoye (year 2001). The soil of the experimental sites was well drained, but shallow with a moisture retention of 16% at 30kPa [23]. The texture varies from sandy loam in the topsoil to sandy clay in the subsoil and is moderately well drained [24]. The soil was classified as a Oxic Paleustalf [25] or Ferric Luvisol [26]. The soil was developed on the sedimentary rocks [27]. The experimental sites have been under continuous maize cultivation for over six years. The sites were disc-ploughed and harrowed to make good seed beds. Trials were laid out as a randomized complete block design (RCBD) with three replications and a plot size of 3 x 4.5 m was used.

The treatments were four rates of N fertilizer

N_0 = Control (no Nitrogen)
N_1 = 75 kg N ha^{-1} (half of the standard recommendation)
N_2 = 150 kg N ha^{-1} (the standard recommendation)
N_3 = 300 kg N ha^{-1} (twice the standard recommendation)

Applied as urea (46%) to two cultivars of improved maize, DMRE-Y and DMR-LSR-W. The improved cultivars were obtained from the International Institute of Tropical Agriculture (IITA) Ibadan, Nigeria. These were planted in the early seasons of both years (April - August) at a planting distance of 90 x 30 cm giving an equivalent plant population of 37,036 plants ha^{-1}.

Standard agronomic recommendations of fertilizers application included single super phosphate (SSP 16%) at the rate of 60 kg P_2O_5 ha^{-1} and muriate of potash (MOP 60%) at the rate of 60 kg K_2O ha^{-1}. These were side dressed at planting and applied uniformly to all the plots. The nitrogen was also side dressed in two equal split dosages that is at planting and at 6 weeks after planting (WAP) at the rates indicated. Weed control was done manually and in two phases, at 3 and 6 WAP. Surface soil samples (0 - 15 cm) were randomly collected from the experimental plots, bulked and composite sample taken for laboratory analysis. Soil sample was analyzed for pH using a soil to water solution of 1:2. Total N was determined according to the method of [28]. Organic carbon was determined as previously described by [29]. Texture was also determined according to the methods of [30]. Exchangeable cations, calcium, manganese and magnesium were determined using atomic absorption spectrophotometer (AAS) while sodium and potassium were also determined by flame photometer. The available P was determined according to the method of [31]. The means of these values for the two locations are presented in Table 1.

Table 1. Result of the soil analysis before the experiments at both sites at a depth 0-15 cm

Soil properties	Season 1 (Abeokuta, year 2000)	Season 2 (Ago-Iwoye, year 2001)
pH	5.8	5.6
Organic carbon (g kg^{-1})	2.10	2.11
Total Nitrogen (g kg^{-1})	2.20	2.00
Available P (mg kg^{-1})	40.50	40.10
Exchangeable Ca (cmol kg^{-1})	0.20	0.30
Exchangeable Mg (cmol kg^{-1})	0.34	0.31
Exchangeable Mn (cmol kg^{-1})	67.79	72.10
Exchangeable K (cmol kg^{-1})	0.40	0.43
Exchangeable Na (cmol kg^{-1})	0.87	0.74
Sand (g kg^{-1})	690	670
Silt (g kg^{-1})	180	170
Clay (g kg^{-1})	170	160

Assessment of disease was at three weekly intervals starting immediately after the second weeding (6 WAP) till harvest. Assessment was done by taking the number of plants diseased in a plot and scoring each infected plant on disease scales of 0 to 6, where 0 was no infection and 6 means plant prematurely killed according to [32]. The disease ratings of each plot were used to calculate the disease index as follows;

$$\text{Disease index} = \frac{\text{Sum of individual ratings}}{\text{Number of plant assessed}} \times \frac{100}{6}$$

where 6 is the maximum disease category.

Data collected were subjected to analysis of variance (ANOVA) and means were separated using the Duncan's multiple range test (DMRT) for disease index, nitrogen, grain yield and other agronomic traits. Simple linear regression analysis was carried out to investigate the relationship between the urea N applied and the disease index.

Data on grain yield and yield components were also collected. Cobs were harvested from the inner rows of experimental plots to measure the grain yield. Kernel row were measured by manually counting the rows of 50 randomly selected cobs. 1000 kernels were randomly selected from threshed kernels of all replicated experimental plots and then weighed using electronic balance. Days to 50% tasseling was measured by randomly selecting 20 maize plants in all the replicated plots when greater than 50% of the plants had developed their tassels. For plant height measurement, 20 randomly selected plants from individual plots located in the inner rows were manually measured when their tassels were fully grown, just before the tassels began to turn dark brown.

Economic analysis was carried out for the cost of urea applied per treatment against the prevailing prices of maize (per kg) in Ogun state as at the time of the study. These costs were collected from the monthly report carried out by the Ogun State Agricultural Development Programme [33]. Since all other costs such as cost of other fertilizers, cost of land preparation, weed control, etc are constant for all the treatments, they are not included in the analysis.

3. RESULTS

3.1 *Macrophomina* Stalk Rot and Increasing N Supply

For the two varieties of maize considered, an increasing N application led to a significant increase in disease index of *Macrophomina* stalk rot. The highest index was observed at 300 kg ha^{-1} N supply for both varieties (Fig. 1). The trend is similar for the two locations during the periods of trial. The susceptibility of the varieties is however different with DMRE-Y being more susceptible to *Macrophomina* than DMR-LSR. Calculation of correlation coefficient for stalk rot, done by pooling the two years' data together for individual cultivars, revealed that there is a strong relationship between the N rates and *Macrophomina* stalk rot (DMRE-Y, r=0.9997; DMR-LSR-W, r=0.9933). A simple linear regression plot is as shown in Fig. 4a and 4b.

The general symptoms noticed include dark brown to black, discolored, decaying or completely rotted roots. The root exuded a brown liquid when the affected tissues are held between fingers. The exudation may depend on the age of the plant.

3.2 *Fusarium* Root Rot and Increasing N Supply

Increasing rate of N application on two different varieties of maize resulted in significant increase in *Fusarium moniliforme* stalk rot index (Fig. 2). There was no significant increase in disease index up to 75 kg N ha^{-1} application of nitrogen. Beyond this rate, further increase in N resulted in increase in disease severity. The highest disease index was observed at 300 kg N ha^{-1}. This same trend was observed in the reaction of the varieties at the two locations during the trial periods. The same method, as used for stalk rot, was also used to determine the interdependence of *Fusarium* root rot index on N rates. A strong relationship was also found for both cultivars (DMRE-Y, r=0.9844; DMR-LSR-W, r=0.9815). The strong relationship can be seen from a simple linear regression plot shown in Fig. 4c and 4d.

The general symptoms noticed include leaves turning from a healthy green color to a dull green and the lower stalk becomes yellowed. When squeezed between the thumb and the index finger at the lower nodes, the stalk often collapses. Mycelia were often seen at the nodes. When split open, the stalks may reveal a pink discoloration.

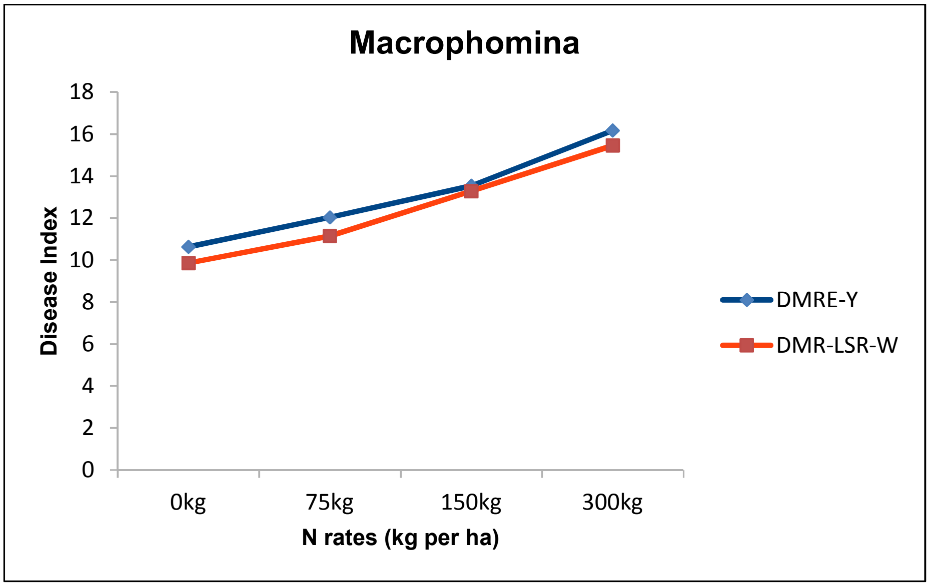

Fig. 1. Disease index for the severity of *Macrophomina* stalk rot of maize as affected by different rates of N (urea) application in Abeokuta and Ago-Iwoye during two planting seasons of 2000 and 2001 for two varieties of maize. Figures are averages of the two years' result

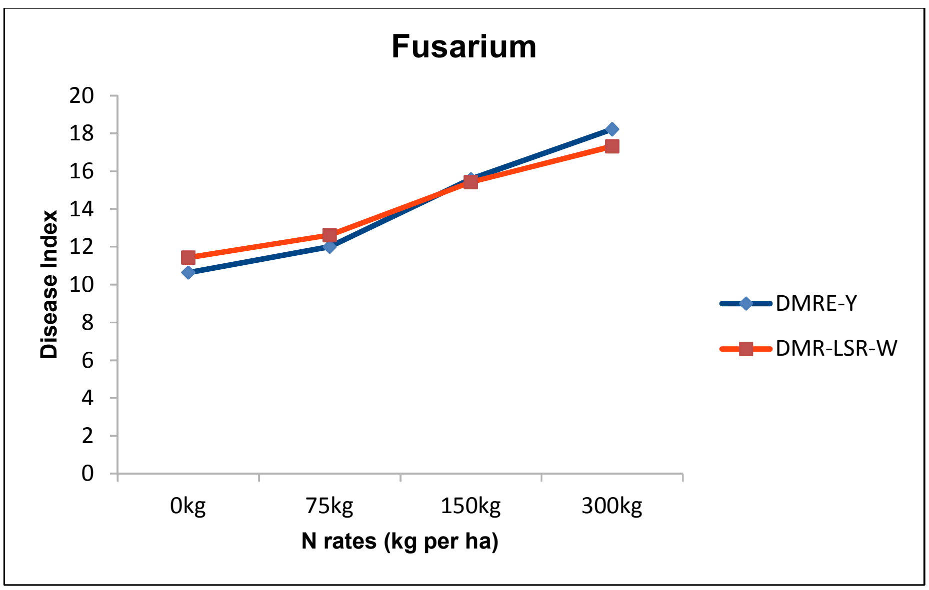

Fig. 2. Disease index for the severity of *Fusarium* root rot of maize as affected by different rates of N (urea) application in Abeokuta and Ago-Iwoye during two planting seasons of 2000 and 2001 for two varieties of maize. Figures are averages of the two years' result

3.3 Effect of Different Rates of Nitrogen on Grain Yield

When urea as an N source was applied at varying rates to maize, it was noticed that N application of 300 kg N ha^{-1} has the highest grain yield for both varieties of maize tested at the two locations. The result in Fig. 3 shows averages of the two trials for the two varieties tested. Generally, the DMR-LSR-W variety showed a higher grain yield in response to the urea applications compared to the DMRE-Y variety. In both varieties, the grain yield increase with an increasing N rates but the differences between the 150 kg N ha^{-1} and 300 kg N ha^{-1} seem not to be appreciable compared to other increases within other N rates.

3.4 Effect of Different Rates of N on the Yield Characteristics

Although the plant height of DMRE-Y variety seems to be insignificantly higher than the DMR-LSR-W variety, there was no noticeable effect of increasing N application on the height of crops in both locations (Table 2). In the DMRE-Y variety, a 300 kg N ha^{-1} rate seemed to bring about a slightly shorter but insignificant plant height for the two years tested.

For the ear length, an increasing N rate did not significantly affect the length of ears, although longer ears were recorded at the 300 kg N ha^{-1} application for both locations. Across varieties, DMRE-Y appeared to be longer than its white counterpart, DMR-LSR-W especially at the higher rate of N applications (Table 3).

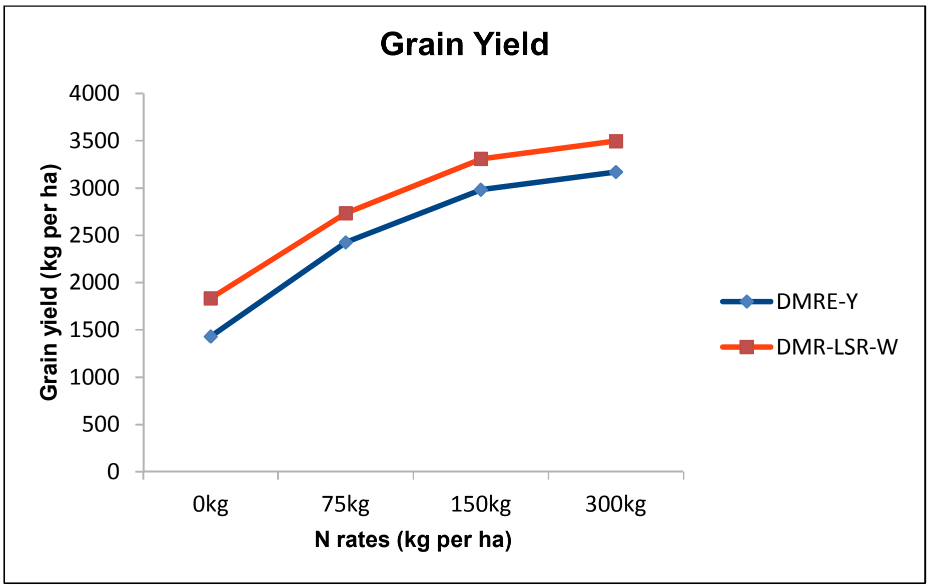

Fig. 3. Average grain yield of maize harvested from two locations of Abeokuta (year 2000) and Ago-Iwoye (year 2001) after different rates of urea fertilizer were applied. The two varieties considered are the commonly grown varieties in southwestern part of Nigeria

Table 2. Effect of different N rates on plant height (m) of two varieties of maize in Abeokuta and Ago-Iwoye during the 2000 and 2001 planting seasons respectively

N rates (kg ha^{-1})	DMRE-Y		DMR-LSR-W	
	Year 2000	Year 2001	Year 2000	Year 2001
0kg	1.88a	1.95a	1.83a	1.85a
75kg	1.96a	2.14a	1.9a	1.83a
150kg	2.05a	2.10a	1.96a	1.76a
300kg	2.03a	2.07a	2.00a	1.79a

•Values followed by the same letters are not significantly different at p < 0.05 according to Duncan's Multiple Range Test

Table 3. Effect of different rates of N on the ear length (m) of two varieties of maize in Abeokuta and Ago-Iwoye during the 2000 and 2001 planting seasons respectively

N rates (kg ha^{-1})	DMRE-Y		DMR-LSR-W	
	Year 2000	Year 2001	Year 2000	Year 2001
0kg	0.65a	0.66a	0.62a	0.61a
75kg	0.64a	0.51a	0.62a	0.59a
150kg	0.72a	0.75a	0.61a	0.55a
300kg	0.74a	0.75a	0.63a	0.60a

•Values followed by the same letters are not significantly different at p < 0.05 according to Duncan's Multiple Range Test

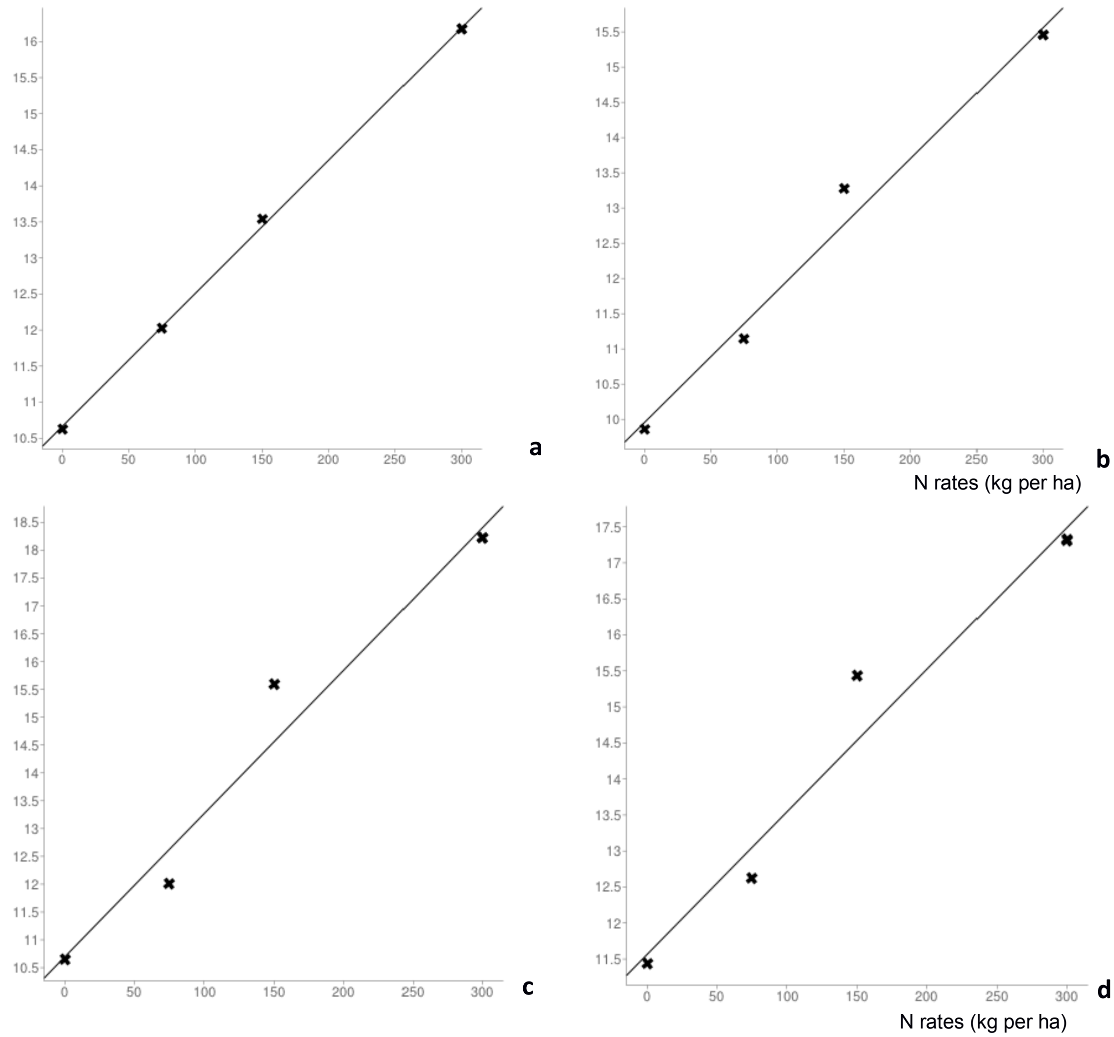

Fig. 4. Relationship between root and stalk rots disease index and N rates treatments, (a) Linear Regression line of best fit for *Macrophomina* stalk rot of DMRE-Y cultivar, (b) Linear Regression line of best fit for *Macrophomina* stalk rot of DMR-LSR-W cultivar, (c) Linear Regression line of best fit for *Fusarium* root rot of DMRE-Y cultivar, (d) Linear Regression line of best fit for *Fusarium* root rot of DMR-LSR-W cultivar, Index values are averages of the two years under consideration

When N rate increased up to 150 kg N ha^{-1}, the kernel row appeared not to be same in the individual cobs but at the highest rate of 300 kg N ha^{-1}, there was a significant change in the kernel rows in both varieties. Comparing varieties, DMR-LSR-W appeared to have more rows at a higher N rate than the yellow variety, DMRE-Y (Table 4).

Table 5 shows the effect of increasing rate of urea as a N source on the 1000 kernel weight of maize. It can be seen that the N rates affected the weight of the kernel especially at the highest rate of 300 kg N ha^{-1}. In the two varieties, the differences between kernel weights with no urea and 300 kg N ha^{-1} applications are all significant (Table 5).

Increase in urea N rates was found to reduce the days to 50% tasseling of maize crops for both varieties (Table 6). The reduction was more pronounced between 'no urea' application and 300 kg N ha^{-1} application, the effects were not too pronounced in-between these two extreme treatments. However, there are significant differences among maize varieties and fertilizer interaction.

The results of the cost-benefit analysis are presented in Table 7. The cost of urea fertilizer was highest for the 300 kg N ha^{-1} but lowest for the zero-urea application. The cost-benefit ratio computed at the prevailing market price (80 Nigerian Naira per kilogram of grain) shows that 300 kg N ha^{-1} gave lowest ratio while 75 kg N ha^{-1} the gave the highest ratio for both varieties in both years.

4. DISCUSSION

The results of this study confirm that the rate of urea fertilizer application has effects on disease pathogen infection and survival and this could affect the differences in yield and yield components.

Table 4. Effect of different rates of N on the kernel row number of two varieties of maize in Abeokuta and Ago-Iwoye during the 2000 and 2001 planting seasons respectively

N rates (kg ha^{-1})	DMRE-Y		DMR-LSR-W	
	Year 2000	Year 2001	Year 2000	Year 2001
0 kg	12.37b	12.22b	12.76c	12.65c
75 kg	12.55ab	12.31ab	13.48c	13.22c
150 kg	12.89ab	12.62ab	13.81ab	13.60ab
300 kg	13.2a	13.07a	14.34a	14.27a

•Values followed by the same letters are not significantly different at p < 0.05 according to Duncan's Multiple Range Test

Table 5. Effect of different rates of N on 1000 kernel weight (kg) of two varieties of maize in Abeokuta and Ago-Iwoye during the 2000 and 2001 planting seasons respectively

N rates (kg ha^{-1})	DMRE-Y		DMR-LSR-W	
	Year 2000	Year 2001	Year 2000	Year 2001
0 kg	0.24a	0.23b	0.23c	0.22b
75 kg	0.25a	0.24ab	0.25b	0.23b
150 kg	0.27b	0.25ab	0.27ab	0.25a
300 kg	0.27b	0.26a	0.28a	0.26a

•Values followed by the same letters are not significantly different at p < 0.05 according to Duncan's Multiple Range Test

Table 6. Effect of different rates of N on days to 50% tasseling of two varieties of maize in Abeokuta and Ago-Iwoye during the 2000 and 2001 planting seasons respectively

N rates (kg ha^{-1})	DMRE-Y		DMR-LSR-W	
	Year 2000	Year 2001	Year 2000	Year 2001
0 kg	66.00a	65.33a	66.00a	65.33a
75 kg	64.33b	63.33ab	65.00ab	64.00b
150 kg	63.33bc	63.33ab	64.33ab	63.00bc
300 kg	62.33c	61.33b	64.00b	62.00c

•Values followed by the same letters are not significantly different at p < 0.05 according to Duncan's Multiple Range Test

Table 7. Cost-benefit analysis of N rates and yield of maize

N rates	Cost of urea (N)	Yield 1 (kg)	Yield 2 (kg)	B/C 1	B/C 2
0 kg	-	1431.01	1834.41	-	-
75 kg	3,000	2426.00	2733.29	64.69	72.89
150 kg	6,000	2983.12	3307.64	39.78	44.02
300 kg	12,000	3170.23	3496.79	21.13	23.32

Yield 1: average yield of years 2000 and 2001 for DMRE-Y variety, Yield 2: average yield of years 2000 and 2001 for DMR-LSR-W variety, B/C 1: Benefit-cost ratio of DMRE-Y variety for the two years, B/C 2: Benefit-cost ratio of DMR-LSR-W variety for the two years; 1 US $ = N 150

The analysis of variance showed that disease index of *Macrophomina phaseolina* was significantly affected by the N rates. The highest disease index occurred when the highest N rate was applied, thereby confirming the data of [34-36]. In this study, plots with no urea fertilizer had significantly low values of *M. phaseolina* infection than the fertilized plots. This might be as a result of the luxurious growth, increased canopy development [37], a wetter plant base/microclimate which favours rot multiplication/survival due to effect on epidemiological parameters [38]. It also favours spore dispersal and possibly plant physiological predisposition [13] to the two diseases tested here. Here, it was noticed that N at an increasing rate increased the susceptibility of maize disease caused by *Macrophomina* due to vigorous growth [38] and availability of nutrients necessary for pathogen development and survival. The increasing disease index as a result of increasing N rate was recorded in both varieties. Although, the year 2001 values are lower than the year 2000 values, probably due to the slight differences in the rate and pattern of rainfall, they simply follow the same format. This simply showed that the effect of urea rate on the *M. phaseolina* severity is independent of the two varieties of maize tested here.

The amount of urea fertilizer applied had a significant effect on the index of *Fusarium root* rot of maize just as obtained for the *Macrophomina* stalk rot. The highest rate of urea fertilizer application resulted in the highest level of disease expression. This might be as a result of the favourable environmental condition for the pathogen to multiply. *Fusarium* is favoured by a dry weather condition prior to silking and warm, wet weather after silking [39]. In this study, a dry weather condition in the early growing seasons (at both locations) followed by an above-average rainfall in the mid season was particularly responsible for the multiplication of the pathogen. He also posited that stresses such as high N, low potassium fertility, high moisture in the mid to late season after a dry early season, moisture stress early in the season and during grain fill, high leaf disease incidence can easily lead to *Fusarium* root rot. A high N rate must have specifically collaborated with other stress conditions to favour the high incidence and severity noticed here. The same trend was recorded for both varieties of maize tested, confirming that the response of the diseases are variety independent [39].

Putting it together, a higher rate of N fertilizer is capable of increasing fungal disease incidence and severity in maize [17] as the vegetative development, plant micro-climate and availability of sustainable nutrient/environment for pathogen multiplication, all work together make the plant more susceptible compared to the control. More succintly, it is a well known fact that plants uitlize urea by cleaving the molecule by soil urease to carbon dioxide and ammonia [40] which can be achieved by many urea-hydrolizing microorganisms (such as *Fusarium* and *Macrophomina*), the result obtained here suggests that there is an increase in the carbon dioxide within and around the roots and stalks of the maize plants. This incremement must have led to a consequential increase in temperature around the plants thereby increasing soluble sugars, hence an increase susceptibility with progressive increase in urea N fertilizer.

To answer the question of whether an increase in disease severity has a consequential reduction in the overall grain output of maize, the grain yield and other yield components were measured. The grain yield revealed an increase after 75 kg N ha^{-1} was applied to maize. The highest grain yield was however recorded at the highest N application rate of 300 kg ha^{-1} for both varieties, thus confirming the data of [41]. However, it is not immediately clear why an increase in yield followed an increase in disease expression across the N rates. A remote reason may be due to the hybrid nature of the varieties of maize used in this research which might be carrying some minimal level of resistance to the diseases at a higher N rate. The overriding effect of higher N availability on the potential of the disease to reduce yield may also be responsible for the increased yield observed. A closer observation at the reduction of days to 50% tasseling of maize plants and comparing it to the higher grain yield at higher N rate seems to suggest that high rates of N application had increased the maize crop early senescence chances thereby decreasing its growth duration due to better development. This must have been followed by a consequential higher dry matter which possibly aided the competitiveness of the maize plants over the diseases at higher N rates. The decline in grain yield at Abeokuta as compared to Ago-Iwoye may be as a result of the complex interaction between negative effect of the disease on yield and the history of the site (which has been under yearly maize cultivation for a long time). More studies are required to investigate the interrelationship of factors of disease index determinant such as fungal pathogens virulence, maize varieties and specific soil/environmental conditions vis-a-vis rates of N fertilizer.

There was relative increase in kernel rows and 1000 kernel weight as N rate was increased [5,41]. Recently, it was posited that in a standard condition, plants with prematurely rotted stalks produce lightweight, poorly filled ears because of the plant's limited access to carbohydrates during grain fill [39] but in this research, urea was made available, varied and supplied in split dosages at early stage of growth (at planting and 6 WAP) which might be responsible for the higher kernel rows and weight especially at 300 kg N ha^{-1}.

If the highest N rate leads to high yield and unexpected high disease severity, it is pertinent to decide which of the N rates will give the best profitability to the farmers. To understand this, the cost-benefit analysis was carried out. Mere looking at the ratio at 75 kg N ha^{-1} application, it would make common sense to 'play safe' and produce at this level considering lower disease expression / severity and high profitability. However, to strike a balance between these factors and other costs, utilization of full potentials of maize yield capability and consideration for other yield parameters, we suggest a urea fertilization of between over 75 kg N ha^{-1} and under 150 kg N ha^{-1}. At this range, the high profitability can still be maintained while keeping down the high severity of disease experienced at 300 kg N ha^{-1}. This can also be confirmed from the grain yield analysis because the yield at 150 kg N ha^{-1} is not significantly different from that of 300 kg N ha^{-1} in both varieties but the cost of urea doubled at 300 kg N ha^{-1} which brought about a canceling effect on the grain yield increase at this highest N rate. However, it is worth noting that the rate of N fertilizer that should be applied, in relation to minimization of disease expression and maximization of yield without raising the production cost, is not easy to define, because it could be influenced by other factors such as planting time, crop density, hybrids, amount and pattern of rainfall, amount of available potassium in the soil, the N absorption capacity of the crop and the soil N content.

5. CONCLUSION

In conclusion, our data have shown that the amount of N applied to maize crop is not only directly proportional to the incidence and severity of the two fungal diseases tested but also affects the grain yields itself. Thus, an optimum N rate which would maximize yield and minimize disease expression and cost of fertilizer should always be the concern of stakeholders before applying nitrogenous fertilizer to maize. In this study, without considering other factors, we proposed 150 kg N ha^{-1}. Further research might be necessary to confirm the exact rate at which these other factors may positively work together with N rates to minimize disease severity and maximize yield.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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