Criticalshoot nitrogen content for potato varietiesAsante and Tigoniin Kenya

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Abstract

Nitrogen is an important nutrient since it has a positive effect growth of plants. Potatoes have low uptake efficiency of nitrogen which is due to the shallow root system thus nitrogen appropriate management is important.Critical nitrogen dilution models and chlorophyll meter can be used to manage nitrogen supply in potato crop. The aim of the study was to develop critical nitrogen dilution model for potatoes in Kenya as well as establish relationship between SPAD index and total shoot nitrogen. Two Field experimentswere conducted in a split plot design at the university of Nairobi farm using potato varieties Asante and Tigoni with three nitrogen fertilizer levels (45, 90, 135 N kg/ha) and a control with no fertilizer application. The critical nitrogen dilution model established is N_c= 5.8$W^{-0.16}$(r^2=0.41)for variety Tigoni and N_c= 6.4$W^{-0.18}$(0.50)for variety Asante with and respectively. A linear relationship between shoot nitrogen content and the SPAD index was established for the two seasons (r^2 = 0.45 and 0.51.)

Key words; Chlorophyll meter, Dilution curve, Potato yield, SPAD, Shoot growth, Nitrogen management

1. Introduction

Importance of Potato (*Solanumtuberosum* L.) in Kenyaas staple and cash crop for smallholder farmers is well documented (Ogola, et al., 2011). Despite all that the average yield levels are still very low about 6.7 ton/ha against a potential of 40 ton/ha. Several factors have been attributed for the low yields which include low or inappropriate application of inputs like clean seeds, fertilizers and control of the major potato diseases (Kaguongo et al., 2008). Fertilizer application for potato among the small scale farmers has been low with only 10-15% of farmers using the recommended rates (Ogola et al, 2011) which may be due to the high cost of inorganic fertilizer and the unavailability of organic manure in good quantity this has led to the low levels of Nitrogen in potato field.

Nitrogen is an important nutrient in crop production since it has a positive effect on chlorophyll concentration, photosynthetic rate, leaf expansion, total number of leaves, plant height and dry matter accumulation and higher yields of potato(Isreal et, al. 2012, Davis et al., 2009,Gathungu et al., 2000,Yassen et al., 2011).Excess soil N can delay maturity of the tubers, reduce tuber specific gravity and result in poor skin set which harms the tuber quality and storage properties (Davis et al., 2009,Yassen et al., 2011).Nitrogen fertilizer management is critical since potatoes have low uptake efficiency of nitrogen which is due to the shallow root system andnitrate leaching (Olivier, 2006). Several diagnostic methods can be used to determine nitrogen status in crops. One of these is the use of critical nitrogen dilution curve.

Critical nitrogen concentrationis defined as the minimum concentration of nitrogen necessary to achieve maximum above ground biomass, at any moment of vegetative growth was developed by Lemaire and Salette (1984) to help in managing nitrogen fertilizer management. Critical N concentration is represented by power equation

$$= \qquad (1)$$

where W is the total shoot biomass expressed in grams per plant, N_c is the total N concentration in shoot biomass expressed as a percentage of the shoot dry matter, and a and b are estimated parameters. a represents the N concentration in the total shoot biomass for 1g DM/plant, and the parameter b represents the coefficient of dilution describing the relationship between N concentration and shoot biomass. Critical nitrogen dilution models for potatoes have been established in other area and for different varieties. The models include $N_c = 4.57W^{-0.42}$for Russet Burbank variety and $Nc = 5.04W^{-0.42}$for Shepody variety in cananda (Belanger et al., 2001), $N_c = 3.6W^{-0.37}$ for potato cultivar Asterix (Andriolo et al., 2006).

The chlorophyll meter is leaf clip-on device that determines theindex of greenness present in plant leaves and thus has been used in nitrogen management.The readings must be calibrated for varieties and other environmental factors in order to be useful, this is due to varietal differences, age of the leaves and environmental differences (Lloyd, 1997). Chlorophyll meter measurements have been correlated with the NNI of various crops (Nicolas et al., 2011, Lorene and Jeuffroy, 2007).

The objectives of this experiment were; (1) to establish the critical nitrogen curve for Asante and Tigoni potato varieties in Kenya. (2) To establish the relationship between SPAD index and the total nitrogen in the shoot of the potato.

2. Materials and Methods

2.1 Experimental site

The experiment was conducted at university of Nairobi farm in Kabete with an altitude of 1737 m above sea level during the long rain 2012 (LR2012) and short rain 2012 (SR2012). The soil type is well-drained, very deep dark reddish, brown to dark red, friable clay classified as a Humic Nitisol according to the soil map of the world and known locally as the Kikuyu Red Clay Loam. The rainfall in the region is bimodal with the long rains (LR) in March to July and short rains (SR) in October to December

2.2 Treatments and experimental design

Clean potato seed of medium size (50g) of varieties Tigoni and Asante were sourced from international potato centerin Nairobi.Compound fertilizer N.P.K 17:17:17 at four levels (0, 45, 90, 135 Kg N/ha) was applied at planting.A split plot design was used with varietiesbeing the sub plot while the fertilizer levelsin the main plot. The experiment was replicated four times.

2.3 Crop management

After initial soil sampling, ploughing and harrowing was done then plotsof 4.5m by 4m werelaid. Fallowsof approximately 10cm deep were dug with a spacing of 75cm between. Fertilizer was then applied in the fallow and mixed thoroughly with the soil. The sprouted potatoes were planted with a spacing of 30cm between tubers. The crop was grown under rain fed conditions. Weedingand hilling was also done twice. Preventive and curative fungicides were sprayed five times each season to prevent and control late blight.

2.4 Data collection

Destructive sampling in which whole plant was uprootedand then underground part separated from the above ground parts at 33, 47 and71 days after planting (DAP) during the long rains 2012 LR2012 and at 32, 45, and 69 DAP in the SR2012. Fresh weight of the two parts was weighed in the field using a digital weighting scale. The samples were oven dried at 65^0c for 72 hours. The nitrogen concentration was determined using the kjeldahlprocedures (Jackson, 1956).

Sequential harvesting was done at 84, 98, and 111 DAP during LR2012 and 69, 84, and 98 DAP inSR2012. Sequential harvesting involved the harvesting of tubers in one entire row.Fresh weight was weighed in the field and tuber samples and shoot samples were collected for oven drying. The tubers were dried for around 96 hours in the oven. The dry weight was then weighed in the laboratory using a digital weighing balance. The remaining three rows were harvested at 126 and 114 DAP during LR2012 and SR2012 respectively.

The chlorophyll content index was measured using Minolta SPAD meter at 33, 47and 71 DAP inLR2012 and at 32, 45 and 69 DAP in SR2012. The measurement was taken in the morning hour at around 10 O'clock on the fourth fully expanded leaf.

2.5 Data analysis

Above ground dry weight, Percent shoot nitrogen, SPAD readings and the sequential harvest datawas analyzed for the variance in the split plot designusing Genstat 13 edition and used to determine the optimum fertilizer level. Bonferoni was used to separate the means.The power equation(1) was regressed using S*tatistical Analysis System*(SAS)9.1.3 portable software. The model was fitted for each of the fertilizer level and varieties separately. 95 percent confidence limits were used to determine the validity of the model with those including zero being rejected.The curve corresponding to optimum yield was selected as the critical nitrogen curve. Regression analysis was also done to establish the relationship between total nitrogen in the plant and the SPAD reading in which a linear model was fitted.

3. Results

3.1 Critical nitrogen dilution model for Variety Tigoni

The results of LR2012 seasonshowed that the models at each fertilizer were significant after non linear regressions (power equation 1), however some of the models had zero within their 95% confidence limits for *a* and (-*b*).The model of $N_c= 5.87W^{-0.1}$ was achieved at recommended fertilizer rate of 90 kg N ha^{-1}. The model had confidence limits of 5.03 to 6.7 for parameter (*a*) and -0.15 to -

0.06 for parameter (-*b*) (Figure 1a).During the SR2012 all models did not contain zero within their 95% confidence limits. The model at the recommended nitrogen fertilizer rate was N_t= 6.39$W^{-0.21}$. The confidence limits were 3.78 to 9.0 for parameter (*a*) and -0.36 to -0.06 for parameter (-*b*) (Figure 1b).During theLR2012most of the points for control were below the curve while those of 135N are above the curve. This is clearer early in the season.These trend was repeated more clearly in the SR2012. However the points at the 45 Kg N/ha are interacting with those of 90 Kg N Ha^{-1}.The model estimates for the recommended fertilizer rate after combining the data for the two seasonswasN_c= 5.8$W^{-0.16}$.

Variety Asante;The results of non linear regression for nitrogen content and the shoot dry weight during LR2012and SR2012were significant and did not include zero within their confidence limits at 95%. The model at the recommended fertilizer rate of nitrogen in Kenya during LR2012 was N_c= 9.51$W^{-0.26}$ and in the SR2012 was N_c= 6.29$W^{-0.20}$.

During LR2012 the dilution curve for variety asante indicate majority of the points were below the curve at the recommended fertilizer rate (figure 2a).DuringSR2012 the dilution model indicated that the points for the control were below the curve and those of 135 Kg Nha^{-1} fertilizer level were above the curve (figure 2b).The model estimates for the recommended fertilizer rate after combining the data for the two seasonswas N_c= 6.4$W^{-0.18}$.

3.2 Relationship between SPAD index and total nitrogen

Linear regression between the SPAD readings and percentshoot nitrogenin LR2012models were SPAD index = 5.03(%N) + 21.68 with r^2 of 0.49 and SPAD index = 5.0(%N) + 21.79 with r^2 of 0.53 for variety Asante and Tigoni respectively. The models in SR2012 were SPAD index = 4.3(% N) +20.59 and SPAD index = 4.56(% N) +23.85 with r^2 of respectively. The probability value for all the regressions were <0.001(figure 3).

4. Discussions

The dilution of the shoot nitrogen concentration with the increase in shoot dry weight occurred during the two seasons. The models in the LR2012 season were quite different (N_c= 5.9$W^{-0.10}$ and N_c= 9.5$W^{-0.26}$ for variety Tigoni and Asante respectively)while in the SR2012 seasons they were more consistent(N_c= 6.4$W^{-0.21}$ and N_c= 6.3$W^{-0.20}$ for variety Asante and Tigoni respectively). Combining the data for the two seasons dilution model of Nc= 5.8$W^{-0.16}$ for variety Tigoni and N_c= 6.4$W^{-0.18}$ for variety Asante with R^2 of 0.41 and 0.50 respectively was reported in this study. Other potato dilution models have previously been developed in other countries and with other varieties.Belanger et al., 2001 reported models of N_c = 4.57$W^{-0.42}$ for Russet Burbank variety and N_c = 5.04$W^{-0.42}$ of Shepody variety in cananda, a model of N_c = 3.6$W^{-0.37}$ for potato cultivar Asterix has also been reported by Andriolo et al., 2006. In Argentina, Giletto and Echeverría, 2012 reported a model of N_c = 5.3$W^{-0.42}$ for cultivar innovator. Differences have been observed in the models from different countries, these differences could be due to the variety differences and also due to the regional ecological differences.

The correlation between nitrogen content and the SPAD index showed a positive relationship with correlation coefficient (r) of 0.58 and 0.75 for the two seasons. These results relates with those reported by Ian and Grady, 2000 who reported a positive correlation with correlation coefficient (r) of 0.71 on St Augustine grass. Increase in SPAD readings in potato leaves with increase in N rate were also reported by other authors (Camilo et al., 2010, Gil et al., 2002). The relationship had a low corresponding r^2 of 0.45 in LR2012 and 0.51 in SR2012. Similarly lower r^2 of between 0.32-0.53 and 0.26-0.42 has been observed on Benjamin fig and cotton wood respectively by Felix et al., 2002.

5. **Conclusion**

Nitrogen is an important nutrient as it has a positive influence on the shoot dry weight and the yields. Applying nitrogen at the rate of 90 Kg N/ha gives optimum shoot dry weight and potato yields.

The model developed for Tigoni was $N_c= 5.8W^{-0.16}$while Asante was $N_c= 6.4W^{-0.18}$comparing these from models developed for other varieties in other area it can be concluded that critical nitrogen dilution models for potato may differ in terms of variety and the region.

The result from the study has shown a linear relationship between SPAD index and the total shoot nitrogen in potato indicating that SPAD meter can be used to predict the nitrogen levels on potato plant. Therefore it can be used in better fertilizer management in potato production systems.

6. **References**

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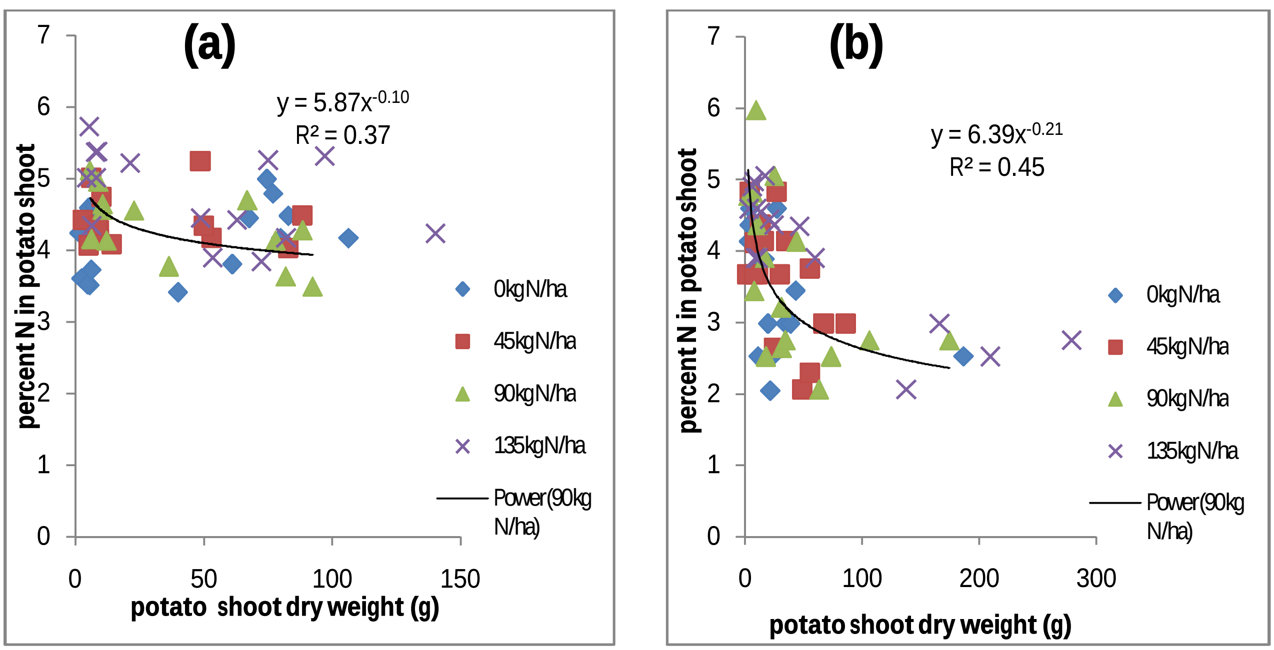
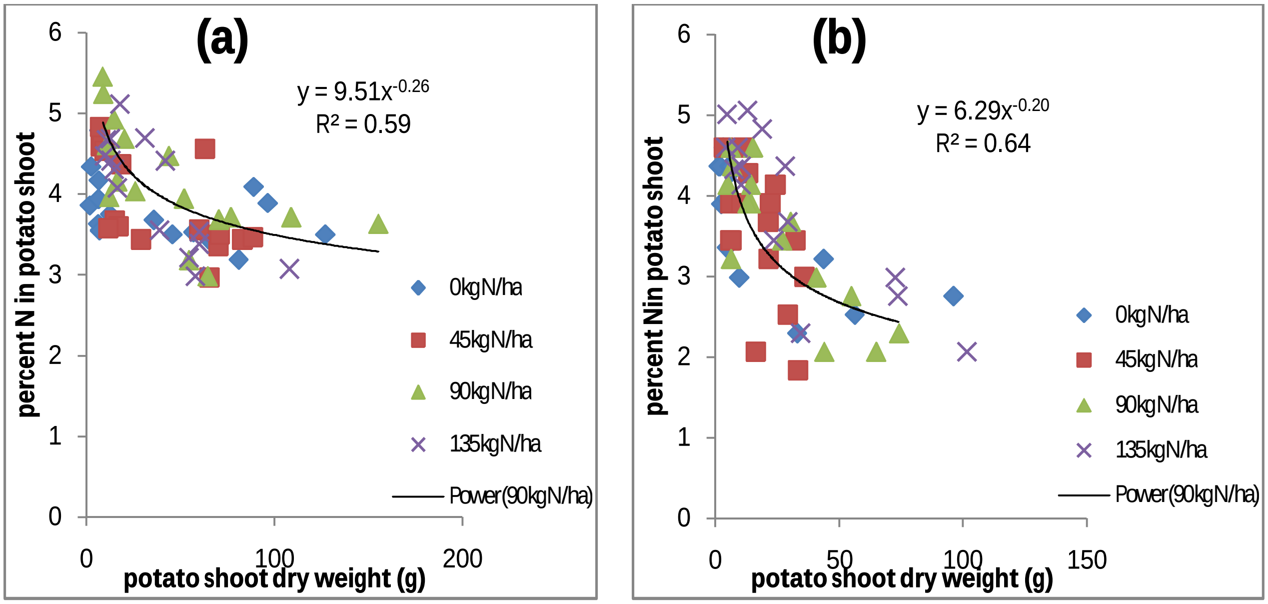


(a) Long rains 2012 (b) short rains 2012

Figure 1. Potato nitrogen dilution models for variety Tigoni in LR2012 and SR2012



(a) Long rains 2012, (b) short rains 2012

Figure 2. Potato nitrogen dilution models for variety Asante in the LR2012 and SR2012

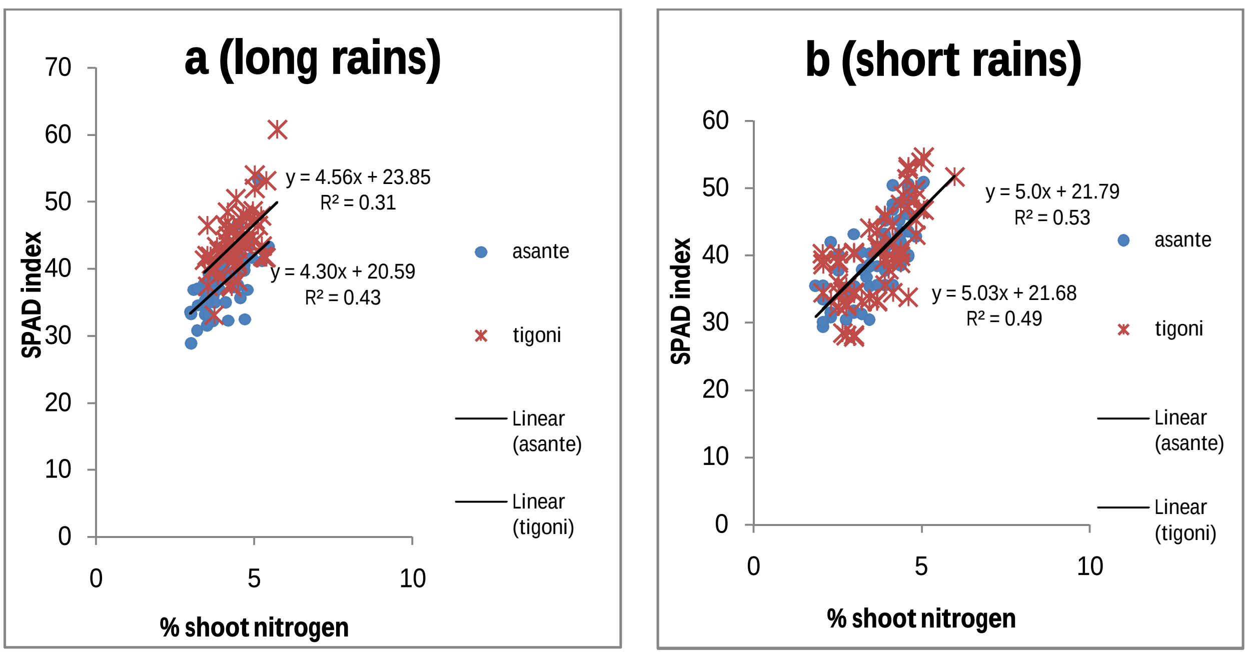


Figure 3; scatter plot of SPAD index against % shoot nitrogen in LR2012 and SR2012