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Effect of Nitrogen Rates on Growth and Leaf Quality of Two Cassava (*Manihot esculenta* Crantz) Varieties at Jimma, South West Ethiopia

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Abstract

Growth and leaf quality are influenced by nitrogen fertilizer management in cassava. Hence, a field experiment was conducted at Jimma in 2016 with the objective of determining the effect of nitrogen on agronomic performance and leaf quality. A 2 × 5 factorial experiment arranged in randomized complete block design (RCBD) with three replications was used. Treatments consisted of two cassava varieties (Kello and Qulle) and five levels of N (0, 40, 80, 120 and 160 kg N ha^{-1}). Variety Kello gave higher leaf area (164.75 cm^{2}), leaf fresh weight (2.61 g), leaf dry weight (1.46 g), longer branch length and stem length (61.23 and 85.81 cm). Higher number of leaf per plant (164) was obtained from Qulle variety. Application of 160 kg N ha^{-1} gave the largest leaf number (186), widest leaf area (184.64 cm^{2}), highest leaf fresh weight (3.10 g), and leaf dry weight (1.65 g). In terms of biochemical composition, kello leaves had higher moisture content (0.43%), ash (18.54%) and crude fat (16.69%). Higher crude fibre (16.24%) and total carbohydrate (27.234%) were obtained from Qulle variety. 160 kg N ha^{-1} gave the highest moisture (0.46%) and the lowest crude fibre (14.12%). The highest leaf nitrogen content (4.802%) and crude protein (30.012%) was gained from the combination of Kello and 160 kg N ha^{-1}. In conclusion, variety Kello and 160 kg N ha^{-1} gave better growth and leaf quality. Similar experiments are suggested at different seasons and locations to draw sound conclusions.

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Keywords

Nitrogen rates (0, 40, 80, 120 and 160 kg ha^{-1}), Cassava (Kello and Qulle), Leaf proximate composition

Introduction

Cassava is a dicotyledonous plant of the family Euphorbiaceae (Okorie *et al.*, 2011). It is mainly produced for its starchy tuberous roots, which are used for human consumption, as animal feed, and as raw material for the starch industry. It is among the most vital tropical crops in terms of source of calorie which includes rice, sugarcane, maize and cassava; it is more cheaply cultivated (Mathews *et al.*, 1993; Reamakers *et al.*, 1993; Nweke, 2004).

The geographical origin was long debated, although it is now believed to be originated from a major center of diversity of the 98 *Manihot* species in Central Brazil. It was largely distributed around the world between the 16th and 19th centuries by European explorers due to its recognition and value as a food and cash crop (Allem, 2002).

Nowadays, cassava is grown in all the tropical countries of the world, including some isolated and remote islands of the pacific (Scott *et al.*, 2000). The major cassava producing areas of the world lie in a band extending from west to east between 100 N and 200 S (FAOSTAT, 2009). The aggregate world cassava production in 2011 was 262.4 million tons from an area of 2.1 million hectares of land. The African share was about 149.5 million tons from an area of 1.3 million hectares. Nigeria, Indonesia, Brazil, and Thailand are predominantly cassava producers, in that order. In 2009, the food supply quantity was around 95 million tons (FAOSTAT, 2012).

Deficiencies in nitrogen can reduce leaf area, photosynthetic rates of leaves; modify branching habit and changes in the distribution patterns of dry matter to different plant parts (Cock, 1984). Nitrogen application influences the quality of leaf especially its protein content (Olsen and Kurtz, 1982; Hofman and Cleemput, 2004). In line with this, the present study was carried out with the aim of determining *the* effect of nitrogen on growth and leaf quality of two cassava varieties under different levels of nitrogen.

Materials and Methods

Description of the experimental site

The experiment was conducted at the experimental field of Jimma University College of Agriculture and Veterinary Medicine, Eladale Site, during 2016 rainy season. It is about 365 km southwest from Addis Abeba on the road to Bedele. The research site is geographically located at 7° 42` N latitude and 36° 50`E longitude with an altitude of 1710 m above sea level. The dominant soils of the area are Nitisol and Cambisol. The area receives an average annual rainfall of 1530 mm. The area has an average maximum and minimum temperature of 26.2 and 11.3°C, respectively and average maximum and minimum relative humidity of 91.40 and 37.92%, respectively (BPEDORS, 2000).

Experimental materials and treatments

Two cassava varieties, namely Kello and Qulle, which were developed and released in 2005 by Hawassa Agricultural Research Centre, were used for this experiment. The treatment consisted of factorial combinations of two cassava varieties (Kello and Qulle) and five different nitrogen rates (0, 40, 80, 120 and 160 kg ha^{-1}). The national blanket fertilizer recommendation for cassava (80 kg N ha^{-1}) was used as a bench mark in the experiment.

Experimental design

The experiment consisted of factorial combinations of two cassava varieties (Kello and Qulle) and five different nitrogen rates (0, 40, 80, 120 and 160 kg ha^{-1}) laid out in randomized complete block design forming 10 treatment combinations each and replicated thrice. Gross plot size was 5 m × 4 m (20 m^2) and the stem cuttings were planted at the spacing of 1 m between rows and 1 m between plants. There were five rows per a single plot and four stem cuttings were planted per row. The total number of stem cuttings per a single plot was 20. The distance between plot and block was 1 m and 1.5 m, respectively leaving the outermost rows on both sides of each plot to avoid border effect. The entire experimental area was 882 m^2.

Experimental procedure

The experimental field was prepared following the conventional tillage practice before planting the stem cuttings. The stem cuttings of about 30 cm long were planted on ridges at 45° according to the recommended space of 1 m by 1 m during the onset of the main rainy season. Urea (46% N) fertilizer was used as a source of nitrogen. The nitrogen fertilizer was divided into two equal split applications and the first half was applied during first month after planting and the remaining half was side dressed three month after planting (DOA, 2009). Numbers of leaves per plant, leaf area, dry and fresh weight of the leaves, branch length, number of stem per plant and stem length were recorded from five randomly selected plants of the middle three rows.

Data collected

Growth parameters: Data were taken from five plants in each plot which were randomly selected from the middle three rows

Number of leaves per plant: Numbers of leaves per plant were determined by counting the leaves on a single plant.

Leaf area (cm^2): Leaf area was measured on graph paper that had one centimeter square grid lines, and the number of grid squares that were inside of the leaf on the paper was the area of the leaf. Based on this, five leave were measured using grid square and the data were recorded as the average leaf area per plant.

Dry weight of the leaves (g): The dry weight of leaves was measured by using a sensitive balance after drying the leaves at 72°C for two days in an oven.

Fresh weight of the leaves (g): The fresh weight of the leaf was measured using sensitive balance.

Branch length (cm): The length of the branches was measured using meter ruler.

Number of main stem per plant: Number of main stem per plant was recorded only by counting the main stems which emerged from the tuber (Zelalem *et al.*, 2009).

Stem length (cm): It was determined by measuring stem length. Five plants in each plot were randomly selected from the middle three rows and their stem lengths were measured using a meter ruler.

Moisture content of the leaf (%): The leaf was measured for its fresh weight immediately using sensitive balance then dried in a hot air oven at 70°C until constant weight was gained to measure its dry weight. The moisture content was determined using the formula indicated below and expressed as percentage (Mbow, 1999).

Leaf proximate analysis

The leaf samples at three different heights of the plant viz., top, middle and bottom, were collected in paper bags and composite leaf samples were made. Leaves were shade dried for three days and then dried in hot air oven at 70°C until constant weight was gained. The dried leaf samples were ground into fine powder and well-maintained in butter paper bags for chemical analysis. Each sample had three replications. As adopted by Sahlemedhin and Taye (2000), crude protein was estimated by multiplying the estimated value of the total nitrogen by 6.25, while the total nitrogen content of the leaf was determined by Kjeldahl method. Techniques and procedures of AOAC (2000) were used to determine crude fibre and crude fat contents. The method of Ranjhan and Krishna (1981) was used to estimate total minerals (ash) composition and total carbohydrates. Accordingly, total carbohydrate was determined by the method of subtracting the percentage values of protein, fat, ash and fibre from 100.

Data analysis

All data collected on different growth parameters and proximate compositions of leaf were first checked for normality and did not violate the rule. The data were subjected to analysis of variance (ANOVA) using SAS version 9.2 (SAS, 2008). Significant differences between treatment means were delineated by least significance difference (LSD) test at the 5% level of significance.

Results and Discussions

Effect of varieties and nitrogen rates on growth of two varieties of cassava

Number of leaves per plant

Number of leaf per plant was highly significantly ($P < 0.001$) affected by nitrogen fertilizer rates. The highest leaf number (186) was recorded at 160 kg/ha-1 of nitrogen fertilizer application. On the contrary, the lowest leaf number (117) was recorded when there was no nitrogen fertilizer application to the varieties. Increasing N fertilizer rate from zero to 160 kg/ha^{-1} increased leaf number from 117 to186. The increase in number of leaves with increase in nitrogen rates may be due to the fact that higher nitrogen concentration stimulated the assimilation of carbohydrates and protein, which in turn enhanced cell division and formation of more tissues that resulted in enhanced vegetative growth of the plant and axillary branches. These results further indicate that number of leaf per plant was favored due to the application of nitrogen owing to availability of more available nutrients in the root zone which up on uptake increase the vegetative growth and leaf numbers. The minimum number of leaf obtained from the control treatment was probably because of the limited vegetative growth of plants due to no N application. Similarly, Uwah *et al.*, (2013) reported that leaf number of cassava was affected by nitrogen fertilizer rate and the highest leaf number was recorded at the highest rate of fertilizer. The number of leaf per plant was higher on Qulle from which 164 numbers of leaves per plant were recorded when compared to kello (146.533). The variations between the two varieties might be linked to genetic factor. Different cassava varieties produce different amounts of foliage, as also reported in previous studies (Simwambana *et al.*, 1992; Phengvilaysouk and Wanapat, 2008).

Leaf area (cm^2)

As shown in this experiment, leaf area of cassava varieties showed statistically significant ($P<0.05$) difference. Kello variety had higher leaf area than Qule variety. Leaf area was 164.75 cm^2/ plant for Kello and 148.89 cm^2/ plant for Qulle. The possible reason for the variation observed in the total leaf area between two cassava varieties could be due to their inherent characteristics. In agreement with the present study, Sinha and Nair (1971) reported that cassava varieties have shown significant variability in leaf area. Increasing nitrogen fertilizer rates increased leaf area of cassava varieties. As a result, the highest leaf area (184.64 cm2) was obtained when highest nitrogen fertilizer rate (160 kg N/ha-1) was applied but not significantly different from 120 kg/ha-1 N applications. The increase in leaf area of cassava with increasing fertilizer rate was probably due to the characteristics of nitrogen fertilizer that promotes higher photosynthetic activity and vigorous vegetative growth and as a result increases leaf size and total leaf area. Previous studies showed that application of nitrogen promoted leaf area (Fox *et al.*, 1975). In support of this finding; Zelalem *et al.,* (2009) also found that increased application of nitrogen rate significantly increased total leaf area of potato. Unlike the result observed above, the smallest leaf area (126.521 cm2) was recorded from cassava grown without any nitrogen. The main reason for smaller leaf area was probably due to the presence of high competition within vegetative growth for available resources and more competition decreased their photosynthetic efficiency that further decreased the vegetative growth and ultimately resulted in smaller leaf area. It can be as well as due to low soil fertility induces small leaves, and the efficiency of photosynthesis decreases with decreasing nutrient concentrations (Howeler, 1985).

Fresh and dry weight of the leaf (g)

As shown in the result (Table 1), increasing the rate of N from 0 to 160 kg ha-1 resulted in increased mean fresh and dry weight of leaves. The highest leaf fresh weight (3.103 g/ plant) was obtained at the highest nitrogen fertilizer level (160 kg/ha^{-1}). The minimum result (1.978 g /plant) was recorded in the control treatment. The highest (1.65 g/plant) dry weight of the leaf was obtained at 160 kg N ha-1 application while the least (1.208 g/plant) dry weight was recorded at control treatment. The increments in leaf dry weight may be due to a combination of nitrogen with plant matter produced during photosynthesis such as amino acids and protein. The fresh and dry weight of the leaf increased because of more vegetative growth of the plants that received more nitrogen. Increasing the rate of nitrogen fertilizer affected leaf dry weight because nitrogen stimulates plant vegetative growth and increases leaf area; as a result, increment in leaf area increases the rate of plant photosynthesis and thus higher dry matter production. The mean fresh weight improvement in response to nitrogen application might be attributed to the increased assimilate production and allocation to the leaf as manifested in terms of increase in number of leaves produced, leaf diameter and leaf length in response to fertilization. Increase in dry weight of a leaf due to increasing nitrogen fertilizer application was reported for potato (Krishnappa, 1989). Fresh weight and dry weight of leaves also showed variation for both varieties. Kello variety had more fresh leaf and dry weights than Qule variety.

Branch length (cm)

Varieties and rates of nitrogen application had significant effect on cassava varieties branch length. This result is supported by the finding of Kedir (2011) who observed variation in branch length among castor genotypes. N application resulted in significant variation in the branch length of varieties. The longest branch length was recorded from the application of 120 kg N ha-1 while the shortest branch length was recorded from the control treatment. The probable reasons for the incremental increase of branch length as the rates of N increased could be the impact of N as one of the major limiting nutrients in plant growth and the adequate supply of N promotes higher photosynthetic activities, vigorous vegetative growth and taller branch length. The branch length increases until the maximum branch achieved might have created high competition between plants for minerals N and the growth and development of plants at this situation makes the plants to produce longer branch length.

Number of stem per plant

The analysis of variance for average number of stems per plant showed that there was no significant influence due to variation in rates of N on the number of stems. Although average number of stems per plant is one of the most important components of growth attributes of cassava, the result of the study showed that the effect of fertilizers and varieties did not result in statistically significant ($P<0.05$) differences for this parameter

(Table 1). Consistent with the current findings, Zelalem *et al.*, (2009) and Mukhtar *et al.*, (2010) found non-significant increase in stem number per plant of potato in response to fertilization. This could be because this trait is much more influenced by the inherent characteristics of the crop than application of fertilizers. In agreement with the result of the current study, previous studies reported that stem number is determined very early in the ontogeny of plant (Dela *et al.*, 1994; Lynch and Rowberry, 1997). According to Susnoschi (1982) and Peter *et al.*, (1988), among the three major yield determining factor of potato (number of stem per plant, number of tuber per stem and average tuber weight), average number of stem per plant depends more on the intrinsic potential of the cultivar than on addition of inputs such as fertilizers. Thus, stem number may be influenced by other factors such as storage condition of tubers, genetic potential of the cultivar, number of viable sprouts at planting, sprout damage at the time of planting and growing conditions (Zelalem *et al.*, 2009).

Stem length (cm)

The result of this experiment revealed that stem length ranged between 62.26 and 92.46 cm, respectively. The longest stem was obtained at 120 kg N ha^{-1} rate and the shortest stem length was obtained at 0 kg N ha^{-1} rate. Increase in nitrogen further increased stem length of the plant. The increased stem length at the highest level of nitrogen was probably due to the availability of more nutrients, which help in maximum vegetative growth of cassava plant. In line with this, when a plant is deficient in N, it becomes yellow in appearance and stunted in terms of growth (Olsen and Kurtz, 1982; Lincoln and Edvardo, 2006).

Longer stem length (85.813 cm) was recorded from Kello variety while shorter stem length (72.533 cm) was obtained from Qulle variety. This variation might be linked to genetic character of the varieties.

Effect of varieties and nitrogen rates and their interaction on leaf proximate composition of cassava varieties

Leaf moisture (%)

Leaf moisture percentage of the two cassava varieties varied highly significantly (P <0.01) with the higher content being from Kello (43.8%) as compared to Qulle (41.8%). Variation in moisture content between varieties could be attributable to their inherent characteristics. The increase in leaf moisture content might be an enhancement in hydrogen ion concentration in plant sap due to the accumulation of chlorides and less moisture loss by evapo-transpiration in the leaves (Eaton, 1942). These results are in conformity with the observations of Basaiah (1988), and Sannappa and Jayaramaiah (2002) who observed variations in moisture content of leaves among castor genotypes.

In this study, application of different rates of N resulted in highly significantly different (P<0.01) moisture content of the leaf per plant. Moisture content of the leaf increased with the increase in the rates of N. The leaf with highest moisture content was found at the rate of 160 kg N ha-1 while least leaf moisture content was documented with no application of Nitrogen (0 kg N ha^{-1}).

Crude fibre (%)

The increase in N rates caused a decrease in crude fibre from 18.82 to 14.12 %. The highest crude fibre of the leaf was documented at no (0 kg/ha^{-1}) nitrogen fertilizer rate while the lowest crude fibre was observed at the highest (160 kgNha^{-1}) nitrogen fertilizer treatment. This shows that increasing nitrogen fertilizer rates decreased crude fibre in the leaf. The decline in crude fibre content with increased N rates could probably be attributed to the fact that plants tend to use more of their photosynthates on protein rather than carbohydrate synthesis. In case of varieties, there was a notable variation between them. Qulle variety revealed higher crude fibre compared to Kello variety. The variation in crude fibre between the varieties may have occurred due to their inherent characteristics. This finding is supported by the finding of Kedir (2016) who recorded significant variation in crude fibre among castor genotypes. Similar to this experiment, Sarmah *et al.*, (2011) also observed variation in crude fibre in different castor genotypes.

Ash (%)

In case of ash content, higher ash content was estimated from the leaves of Kello (18.54%) variety. The main reason for variation in ash content between the varieties could be due to genetic factors. Kedir (2016) observed significant variation in ash content between eight different castor genotypes. Ash content may also vary due to variation in metal composition in the same plant of different variety (Selema and Farago, 1996). On the other hand, application of different rates of nitrogen highly significantly (P<0.001) influenced ash content of the leaf per plant. Ash content of the leaf increased gradually with the increase in the rates of N. The leaf with highest ash content (19.17%) was recorded at the rates of 80 kg N ha^{-1} while lower leaf ash content (15.435%) was recorded with no N application (0 kg N ha^{-1}). This low ash content is indicative of the low mineral content of cassava (Adepoju and Nwangwu, 2010).

Crude fat (%)

The increase in nitrogen caused an increase in crude fat of leaf. The highest crude fat recorded in the cassava leaf (18.45 %) was registered at the rates of 120 kg N ha^{-1} application. Crude fat which includes all lipids, chlorophyll, carotenes and all other fat soluble material tends to be enhanced by nitrogen application (Mengel, 1979). The least crude fat content (13.43%) was recorded with no application of N (0 kg ha^{-1}). Crude fat content between two cassava varieties varied highly significantly with higher content being from Kello as compared to Qulle. Variation in crude fat content between varieties could be attributable to their difference in terms of their inherent characteristics. Consistent with the current findings, Sarmha (2011) and Kedir (2014) observed variation in fat content among castor genotypes.

Total carbohydrate (%)

The total carbohydrate which was analyzed on dry weight basis as a difference in the sum of ash, crude protein, crude fat and crude fibre from 100% also revealed significant variation for different rates of nitrogen and two cassava varieties. Qulle recorded higher carbohydrate content of 27.23% while Kello registered 22.78% (Table 2). The difference in total carbohydrate content between the two varieties might be attributed to the variation in genetic factors. The present observation is in agreement with the findings of Govindan *et al.*, (2003a, b) and Chandrappa *et al.*, (2005) who detected variation in the total carbohydrate content among castor genotypes. With regard to N, the highest total carbohydrate was gained from application of 0 kgN ha^{-1}. Limited N supply results in higher level of carbohydrates (Hehl and Mengel, 1972; Mengel, 1979). The lowest total carbohydrate was obtained from the highest application of N (160 kg/ ha^{-1}).

Table.1 Effect of two cassava varieties and nitrogen rates on fresh and dry weight of cassava leaf, branch length and number of stem perplant at Jimma, south west Ethiopia during 2016 cropping system

Factor	Cassava growth parameter						
	NLPP	LA (cm^2)	FWL (g)	DWL (g)	BL (cm)	NSPP	SL (cm)
Varieties							
Kello	146. 46^{b}	164.75^{a}	2.62^{a}	1.47^{a}	61.23^{a}	3.37^{a}	85.81^{a}
Qulle	164.46^{a}	148.89^{b}	2.42^{b}	1.39^{b}	51.31^{b}	3.36^{a}	72.53^{b}
LSD (5%)	10.40	10.977	0.06	0.04	4.77	0.44	7.28
N (kgha^{-1})							
0	117.33 ^{d}	126.52 ^{d}	1.98^{e}	1.21^{e}	40.13^{d}	3.4^{a}	62.26^{d}
40	142^{c}	144.22^{c}	2.22^{d}	1.31^{d}	49.57^{c}	3.47^{a}	72.73^{cd}
80	158.33^{bc}	156.79^{bc}	2.47^{c}	1.43^{c}	58.5^{b}	3.47^{a}	80.43 ^{bc}
120	173.33^{ab}	171.93^{ab}	2.81^{b}	1.56^{b}	68.2^{a}	3.47^{a}	92.46^{a}
160	186.5^{a}	184.64^{a}	3.102^{a}	1.65^{a}	64.93^{ab}	3.87^{a}	87.96^{ab}
LSD (0.05)	16.44	17.35	0.1	0.07	7.54	ns	11.51
CV (%)	8.72	9.12	3.24	4	11.12	23.63	12.07

NLPP = Number of leaf per plant, LA= Leaf area, FWL= Fresh weight of the leaf, DWL= Dry weight of the leaf, BL= Branch length, NSPP = Number of stem per plant, LSD = Least significant difference and CV = Coefficient of variation. Means followed by the same letters with in a column are not significantly different at 5% p level.

Table.2 Effect of varieties and rates of nitrogen on proximate leaf composition of two cassava varieties at Jimma, south west Ethiopia during 2016 cropping system

Factor	Cassava leaf mineral composition				
	Moisture (%)	Crude fibre (%)	Ash (%)	Crude fat (%)	Total carbohydrate (%)
Varieties					
Kello	43.8[a]	15.06[b]	18.54[a]	16.69[a]	22.79[b]
Qulle	41.8[b]	16.25[a]	17.68[b]	15.99[b]	27.23[a]
LSD (5%)	0.01	0.48	0.16	0.22	0.66
N (kgha^{-1})					
0	38.8[e]	18.83[a]	15.44[d]	13.44[e]	31.03[a]
40	40.8[d]	16.11[b]	18.39[c]	15.83[d]	26.42[b]
80	43[c]	15.07[c]	19.17[a]	16.17[c]	24.92[c]
120	44.6[b]	14.14[d]	18.82[b]	18.49[a]	22.46[d]
160	46.7[a]	14.13[d]	18.74[b]	17.76[b]	20.25[e]
LSD	0.014	0.771	0.25	0.35	0.97
CV (%)	2.747	4.089	1.17	1.76	3.21

LSD = Least significant difference; CV = Coefficient of variation. Means followed by the same letters within a column are not significantly different at 5% P level.

Table.3 Interaction effect of varieties and nitrogen rates on nitrogen and crude protein content from the leaves of varieties of cassava at Jimma, south west Ethiopia during 2016 cropping system

Variety	Cassava leaf proximate composition		
	Nitrogen (kg ha^{-1})	Nitrogen (%)	Crude protein (%)
Kello	0	3.546[f]	22.162[f]
	40	3.833[e]	23.956[e]
	80	4.114[d]	25.712[d]
	120	4.283[c]	26.768[c]
	160	4.802[a]	30.012[a]
Qulle	0	3.26[g]	20.376[g]
	40	3.608[f]	22.553[f]
	80	3.779[e]	23.620[e]
	120	4.068[d]	25.424[d]
	160	4.513[b]	28.205[b]
LSD (5%)		0.092	0.575
CV (%)		1.35	1.35

LSD = Least significant difference; CV = Coefficient of variation. Means followed by the same letters within a column are not significantly different at 5% P level.

Leaf nitrogen (%)

The highest leaf nitrogen was recorded from Kello variety with the application of 160 kg N ha^{-1} while the lowest nitrogen content was obtained from Qulle with no application of N. Leaf nitrogen content ranged between 3.40 and 4.65%. There was also variation between the two cassava varieties. Kello had higher nitrogen content in its leaf than Qulle. This result is in agreement with the findings of Kedir (2011), Sarmah *et al.*, (2011) and Chandrashekhar *et al.*, (2013) who observed significant difference among castor genotypes in terms of nitrogen content. In the same manner, EL-Shaarawy *et al.*, (1975a) also recorded different amount of nitrogen from different varieties of castor.

Crude protein (%)

From the interaction point of view, the highest leaf crude protein (30.012%) was recorded from Kello variety with the application of 160 kg N ha^{-1} while the lowest crude protein (20.37%) was obtained from Qulle variety with no application of nitrogen (Table 3).

Higher crude protein content was obtained from Kello variety. The variation in the crude protein content between the two varieties may at least partly be attributed to genetic factor. Basaiah (1988), Sannappa and Jayaramaiah (2002), Govindan *et al.,* (2003a, b) and Chandrappa *et al.*, (2005) recorded variation in crude protein content among castor genotypes.

Crude protein which is 6.25 times the nitrogen content (Lord, 1968) varied markedly among different rates of nitrogen. The lowest crude protein was gained from no application of nitrogen (0 kg N ha^{-1}) whereas the highest crude protein was obtained from the application of the highest nitrogen (160 kg N ha^{-1}). The possible reason for the incremental increase in protein content as the application of nitrogen increased could be due to the fact that nitrogen is utilized to synthesize amino acids, which in turn form proteins (Olsen and Kurtz, 1982; Hofman and Cleemput, 2004).

In conclusion, it was found that varieties and rates of nitrogen showed highly significant influences on plant agronomic performance, leaf mineral and nutrient composition (Leaf quality). Variety Kello produced higher value for plant growth attributes (leaf area, leaf fresh and dry weight, branch length, and stem length) and leaf nutrient contents (moisture, ash and crude fat) while Qulle variety bettered on number of leaves per plant and crude fibre.

Nitrogen application at 160 kg N ha^{-1} resulted in maximum value for growth attributes (number of leaf per plant, leaf area, fresh and dry weights of leaf and branch length) and moisture of leaves. The highest values for crude fibre and total carbohydrate were recorded from no application of nitrogen. Combined application of 160 kg N ha-1 and use of Kello cassava variety showed higher mean number for nitrogen and crude protein content of leaves. The least recorded value in all parameters was from the control treatment except for crude fibre and carbohydrates.

The results in general pointed out the positive effect of nitrogen fertilizer which improved most of the quality of leaves and agronomic parameters studied. Variety Kello and 160 kg N ha-1 resulted in maximum growth and leaf quality. In addition, similar research should further be conducted at different locations and seasons to validate the results.

Conflict of interests

The authors have not declared any conflict of interests.

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