Research Article

The effect of two fertilizer types on growth, yield, gluten content of two Cameroon wheat landraces.

Lendzemo, E. Tatah[1*], Mofor L. Nyagarlouh[1]., Tabi Kingsley Mbi[1], Abwe M. Ngone[2]., Tange, D. Achiri[2,3]., Njualem, D. Khumbah[1,4].

[1]Department of Crop Production Technology, College of Technology, University of Bamenda, P. O Box 39. Bambili, NWR, Cameroon.

[2]Department of Agronomic and Applied Molecular Sciences, Faculty of Agriculture and Veterinary Medicine, University of Buea. P. O Box 63. Buea, Cameroon.

[3]Department of Agronomy, School of Agricultural Science, Biaka University Institute, P. O. Box 77. Buea, SWR, Cameroon.

[4]School of Tropical Agriculture and Natural Resource, Catholic University of Cameroon, P. O Box 782. Bamenda, NWR, Cameroon.

Abstract

Wheat (*Triticum aestivum*) is one of the most important cereals in the world, providing 20% of calories in the daily diets of the world. Wheat is highly consumed in Cameroon directly or processed into bread and biscuits. However, the need to increase quality wheat production in Cameroon is emphasized especially in the wake of the geopolitical crisis between Ukraine and Russia. This study was designed to ascertain the impact of two nitrogen sources (urea and Ammonium sulphate) at different doses (0g, 2g, 4g and 6g) per plant on growth, yield and gluten content of two Cameroon landraces of wheat (Boyo and Adamawa). In April 2022, a split plot experiment with landrace as main plots and fertilizer doses as subplots was established in the research field of the Regional College of Agriculture Bambili, North West Region of Cameroon. Plant height did not vary across fertilizer doses but Boyo was significantly taller than Adamawa ($P < 0.05$). The number of leaves and the number of tillers progressively increased with fertilizer doses. The number of spikes increased with increased fertilizer doses and the values for Boyo were higher than those for Adamawa for corresponding doses. Interaction effects of variety x dose was significant ($F = 7.162$, $df = 3, 40$, $P = 0.001$) on the number of grains with Boyo and Adamawa landraces producing 331 and 320 grains per plant, respectively from 6g of urea. Boyo and Adamawa produced 337 and 449, from 6g and 4g of ammonium sulphate respectively. Grain weight and gluten content increased with increase doses of fertilizers with the highest grain weight and gluten content from Adamawa landrace at 6g of ammonium sulphate per plant.

The Adamawa landrace at 6g per plant of ammonium sulphate is recommended for increased yield and gluten. Other ramifications are discussed.

Keywords: Adamawa, ammonium sulphate, Bambili, Boyo, fertilizer dose, urea

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Résumé

Le blé (*Triticum aestivum*) est l'une des céréales les plus importantes au monde, produisant 20 % des calories dans l'alimentation quotidienne. Le blé est très consommé au Cameroun et est tres souvent transformé en pain et en biscuits. Cependant, la nécessité d'augmenter la production de blé de qualité au Cameroun est particulièrement soulignée suite à la crise géopolitique entre l'Ukraine et la Russie. La présente étude a été conçue pour vérifier l'impact de deux sources d'azote (urée et sulfate d'ammonium) à différentes doses (0g, 2g, 4g et 6g) par plante sur la croissance, le rendement et la teneur en gluten de deux variétés locales de blé du Cameroun (Boyo et Adamawa). En avril 2022, une expérience en parcelles divisées avec des variétés locales comme parcelles principales et des doses d'engrais comme parcelle secondaire a été mise en place dans le champ expérimental du Collège régional d'agriculture de Bambili, dans la région du Nord-Ouest Cameroun. La hauteur des plantes ne variait pas selon les doses d'engrais, mais Boyo était significativement plus grand qu'Adamawa ($P < 0,05$). Le nombre de feuilles et le nombre de talles a progressivement augmenté avec les doses d'engrais. Le nombre d'épis a augmenté avec la croissance des doses d'engrais et les valeurs pour Boyo étaient supérieures à celles d'Adamawa. Les effets d'interaction variété x dose étaient significatifs ($F = 7,162$, $df = 3, 40$, $P = 0,001$) sur le nombre de grains, les variétés locales Boyo et Adamawa produisant respectivement 331 et 320 grains par plante à partir de 6 g d'urée. Boyo et Adamawa en ont produit 337 et 449, à partir respectivement de 6 à 4 g de sulfate d'ammonium. Le poids des grains et la teneur en gluten ont augmenté avec l'augmentation des doses d'engrais avec le poids de grain et la teneur en gluten les plus élevés de la race locale Adamawa, soit 6 g de sulfate d'ammonium par plante.

La variété locale Adamawa à 6 g par plante de sulfate d'ammonium est recommandée pour accroitre le rendement en grain et le gluten. D'autres ramifications sont discutées.

Mots clés : Adamawa, sulfate d'ammonium, Bambili, Boyo, dose d'engrais, urée

1. Introduction

Wheat (*Triticum aestivum*) is a cereal of worldwide significance which belonging to Poaceae (Graminae) (Behzad et al., 2021). Wheat plays a very important role in global economy as it is used to make flour for bread, cookies, biscuits, leavened, breakfast cereals, cake, pasta, fermented alcoholic beverages (beer), noodles and bio-fuel (Ibukun and Moyin, 2018). In addition, wheat is consumed directly as a staple for millions all over the world after rice (Kamboj et al., 2022) providing 20% of calories in the daily diets of the world's population (Shiferaw et al., 2013). Wheat serves as a source of nutritive fiber for humans and livestock (Sherry, 2009; Ullah et al., 2018). On the global stage, wheat occupies more than 30% of whole grain demand. The increasing global population has warranted the augmentation of wheat productivity and proper distribution to avoid future world food insecurity shocks (Hussain et al., 2013). China, India, and Russia are the three major producers of wheat with about 41% of world's total wheat production (FAO, 2022). About 30.0% of global wheat trade is accounted for by Russia and Ukraine (Lin et al., 2023). The conflict between Russia and Ukraine has derailed global wheat supplies, leading to high prices, worsened hunger and malnutrition for many in about 36 – 53 countries especially in the developing world (Balma et al., 2022; Mottaleb et al., 2023). To avoid future food shocks, Mottaleb et al. (2023) proposed that developing countries expand domestic wheat production.

Over a period of two decades (2000 – 2019), Shillie et al. (2022) reported that annual wheat production in Cameroon was 840 metric tons. At the same time, wheat importation to

Cameroon was 513850 metric tons annually (Shillie et al., 2022). Thus, the mismatch between local production and consumption need is filled through importations, with Ukraine supplying about 60% of wheat consumed in Cameroon (Kindzeka, 2022). Cameroon has the requisite agro-ecological conditions for wheat production, therefore engaging in local wheat production can create jobs and avoid food insecurity (Shillie et al., 2022). The government of Cameroon invested 15 million USD (~ 10 billion CFA) to grow more wheat in 2022 (Kindzeka, 2022). In order for such initiatives to be successful, especially in areas where farmers have limited knowledge of wheat cultivation, it is important to ensure that wheat is cultivated under sustainable farming systems. One of such sustainable farming systems to consider is the proper use of agricultural farm inputs such as agrochemical like fertilizers.

Fertilizer application in agricultural system is known to improve growth and yield parameters of agricultural crops (Ouda and Mahadeen, 2008; Ngosong et al., 2019; Lin et al., 2023) and wheat in particular (Gasser and Iordanou, 1967; Kobata, 2012, Ramirez-Wong et al., 2014; Khursheed and Mahamad, 2015; Cui et al., 2023). While fertilization largely controls growth and yield of wheat, it is also hugely implicated in the quality of grain protein which is necessary for baking and processing (Zorb et al., 2018; Wilson et al., 2020). Gluten protein in the form of gliadins and glutenins are key determinants of dough elasticity and extensibility, characters highly desired by the baking and processing industry (Kong et al., 2013; Yang et al., 2022). In fact, it is reported that an increase in nitrogen (N) rates was significantly correlated with an increase in all protein components, gliadins and glutenins, leading to increase bread volume (Johnson et al., 2001). In addition to soil fertility and crop nutrition, Horvat et al. (2021) argues that yield quality (protein and protein components such as gluten) of wheat is also dependent on genotype and growing conditions.

The effect of many agronomic parameters on the growth, yield and composition of wheat gluten has been widely studied globally (Ramirez-Wong et al., 2014). However, there is a dearth of knowledge regarding optimal agronomic status to produce bread with good-quality gluten in Cameroon. This study was designed to (i) examine the growth and yield performance of two Cameroon landraces of wheat under two nitrogen sources and (ii) to ascertain the gluten content in order to reduce knowledge gap, and improve grain quality and quality of local wheat production.

2. Materials and methods

2.1 Experimentation Site

The experiment was conducted at the experimental field of the Regional College of Agriculture (RCA) Bambili with coordinates 6.013896 ^{0}N and 10.263518 ^{0}E of the North West Region of Cameroon, Tubah Sub Division. Gluten content studies was conducted in the Food Science Technology Laboratory, College of Technology, University of Bamenda, in Tubah Subdivision of the Northwest Region of Cameroon. It lies between longitudes 10.259319 ^{0}N and latitudes 6.011374 ^{0}N. The zone has two seasons, the dry and wet seasons range from November-April and May-October respectively. The mean annual rainfall is about 2200 mm with July, August and September registering the highest rainfall and December the lowest. Also, the mean annual temperature is about 20.67°C with January and February registering the highest and July, August and September the lowest temperature (Yuninui, 1990). The soils in Tubah sub division are volcanic which contain black quarries and laterite pits for construction. The drainage system is very rich with streams and springs emanating from the northern belt. The present vegetation of Tubah consist mainly savannah ecosystem, with the *Poaceae* of *Grammeae* plants forming the main vegetation layer interspersed with a few other annuals, perennials, and trees. According to Ngwa and Fonjong (2002), the vegetation of this region is both natural and cultivated. The cultivated vegetation consists of planted trees like cola nut, eucalyptus, raffia palm and other fruit trees. Its forested area is located in the northern part of the subdivision (Melle *et al.,* 2016).

3.2. Collection of plant materials

Two morphologically distinct wheat landraces in Cameroon were used; wheat from Boyo (Fundong) and wheat from the North (Adamawa) these were collected from the local farmers of the area.

2.3. Treatments and experimental design

The landraces, Boyo and Adamawa were fertilized using urea and ammonium sulphate at different doses. A split plot in a randomised complete block design with three replicates was used. The wheat landraces were the main plots and fertilizer type and doses (Urea 46%, AGRI INPUT Cameroon: 0g plant^{-1}, 2g plant^{-1}, 4g plant^{-1}, 6g plant^{-1}; Ammonium sulphate 21%, AGRI INPUT Cameroon: 0g plant^{-1}, 2g plant^{-1}, 4g plant^{-1}, 6g plant^{-1}) were the subplot. Thus, a total of 48 experimental units. Each subplot measured 2.5 x 0.5 m (1.25m^2) and separated by a crop-free zone of 80cm wide to limit inter-plot interference. Blocks were separated from each other by 1 m gap. Borders of 1 m were also kept round the experimental area. The gross experimental area of 9.5 m x 15.6m (148.2m^2) was used.

2.4 Site preparation and crop establishment

The field was cleared with a cutlass and the grasses wrecked and carried to the borders on February 27 2022. It was later ploughed manually by means of hoes and diggers. The field was demarcated as per the experimental design and allowed for two weeks before planting in order for early rain to properly irrigate the area. Four seeds were sown 5 cm deep, at a spacing of 24 cm intra row and 65 cm inter row on the April 04 2022. Each stand was later thinned to two plants. Every experimental unit had 40 plants. The field relied extensively on rainfed irrigation. A three – split fertilization (urea and ammonium sulphate at different doses) was done at (a) tillering, (b) elongation and (c) heading (Pechanek et al., 1997; Zorb et al., 2018). Moulding was done after fertilization. Weeding was done *ad libidum*. A broad-spectrum fungicide Pencozeb 80 WP (Mancozeb 80%, Tunisia), was applied once a week from week six, when fungus attack was observed. The fungicide was applied as per the recommendation of the manufacturer using a manually-pumped knapsack sprayer of 16L capacity, at 10g of the fungicides per 16L of water. Two scare crows were mounted in each black to scare birds away.

2.5. Data collection

2.5.1. Plant height (cm)

Average plant height was recorded 8 weeks after planting when anthesis was observed. Six plants were selected randomly and measured from the base to the apex of the last leaflets. The average of the 6 plants was computed and entered as plant height per treatment.

2.5.2 Number of leaves

Average number of leaves was recorded 8 weeks after planting. Six plants were selected randomly and the number of leaves counted. The average of the 6 plants was computed and entered as number of leaves per treatment.

2.5.3 Number of tillers

Average number of tillers was recorded 10 weeks after planting. Six plants were selected randomly from each plot and the number of tillers counted. The average of the 6 plants was computed and entered as number of tillers per plant.

2.5.4. Number of spikes

Average number of spikes was recorded 10 weeks after planting. Six plants were selected randomly from each plot and the number of spikes counted. The average of the 6 plants was computed and entered as number of spikes per plant.

2.5.5. Spike length (cm)

Average spike length was recorded after harvesting. Fifteen spikes were randomly selected after harvesting from each treatment and their lengths measured from the base to the apex. The average of the 15 spikes was computed and entered as spike length per plant.

2.5.6. Spikelets per spike

Average number of spikelets was recorded after harvesting. Fifteen spikes were randomly selected after harvesting from each treatment and the number of spikelets counted. The average was computed and entered as number of spikelets per plant.

2.5.7. Grains per spike

Fifteen spikes were selected randomly after harvesting from each treatment and threshed. The number of grains per spike were counted. The average was computed and recorded as grains per treatment.

2.5.8. Grain weight (g)

Fifteen spikes were selected randomly after harvesting from each treatment and threshed. The grains obtained from the fifteen plants were weighed (g) and the average was computed and recorded as grain weight per plant.

2.5.9. Assessment of gluten content

The grains obtained were sundried and crushed using a locally design mill to obtain flour. Fifteen ml of water was added to 25g of each flour sample and the content was thoroughly knead by hand for around 10 minutes, when the dough appeared smooth and was able to stretch easily without breaking. The dough ball was immersed in a 250 ml beaker containing water for one hour. A bowl (diameter = 15cm, height = 15cm) serving as a receiver of the washing was placed under running water and a sieve was put on it. Continuous washing of the dough was done in order to remove the starch. Observations indicated that upon addition of iodine solution to the washings, blue-violet coloration implied presence of unwanted starch. Washing continued until the water beneath the sieve was clear and no more blue coloration was observed, indicating that all the starch was removed. The adhered water was squeezed out from the extracted gluten and weighed to get the wet gluten. It was later dried at 135 ºC for 2 hours and weighed again to get the yield of dry gluten expressed in percentage (Equation 1).

$$Drygluten(\%) = \frac{Weightofdrygluten}{Weightofsampletaken} x100$$

…………………… eq. 1

2.6. Data analysis techniques

Data collected were keyed unto an excel sheet for coding and analysis. Data were analyzed using SPSS (ver. 23). A full factorial analysis of variance (ANOVA) was used ascertain the interaction and main factor effects on the measured parameters. Where means were significantly different, they were separated using Duncan's Multiple Range Test (DMRT) *posthoc test* at alpha (á) level of 0.05. Where the blocking effect was not statistically significant, the ANOVA was redone with the blocking effect removed in order to increase the degree of freedom of the error term, thus increasing the reliability of the analysis (Achiri et al., 2021).

3. Results

3.1 Plant height (cm)

The plant height was not significantly affected by any interaction effect: variety x fertilizer x dose

(F = 0.493, df = 2, 26, P = 0.616), variety x fertilizer (F = 0.435, df = 1, 26, P = 0.516), variety x dose (F = 0.543, df = 3, 26, P = 0.657), fertilizer x dose (F = 0.175, df = 2, 26, P = 0.840) (Table 1). The plant height was principally dependent on variety (F = 55.223, df = 1, 26, P = 0.001), irrespective of fertilizer type and dose. Using urea, the grand mean plant height of Boyo (53.41 cm) was statistically higher ($P < 0.05$) than that of Adamawa (31.81 cm). The same pattern was observed for plant height using Ammonium Sulphate ($P < 0.05$) with Boyo (46.78 cm) higher than that of Adamawa (29.36 cm) (Table 1).

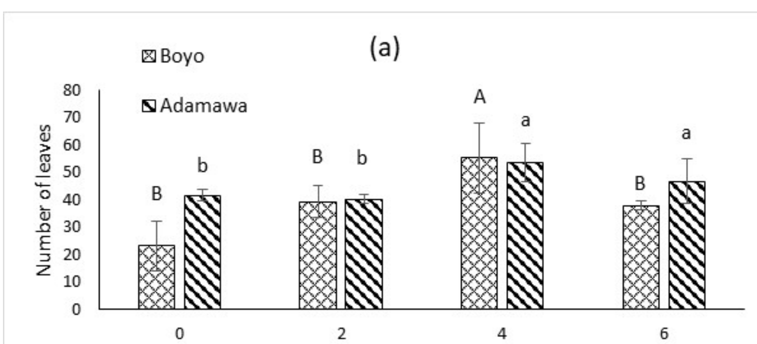
Table 1. Response of plant height (cm) of two wheat varieties to different fertilizers.

Dose (g)	**Urea**		**Ammonium Sulphate**	
	Boyo	**Adamawa**	**Boyo**	**Adamawa**
0	51.22 ± 8.28a	33.11 ± 15.63a	43.57 ± 4.72a	21.95 ± 7.73a
2	50.53 ± 10.59a	28.11 ± 9.57a	46.55 ± 7.37a	22.00 ± 7.64a
4	53.33 ± 9.61a	28.33 ± 7.55a	46.22 ± 2.83a	32.44 ± 9.39a
6	53.55 ± 6.61a	37.67 ± 4.09a	47.55 ± 9.72a	33.66 ± 7.57a
Grand mean	53.41 ± 7.87	31.81 ± 9.56	46.78 ± 6.29	29.36 ± 9.05
	$P < 0.05$		$P < 0.05$	

Means (± standard deviation) within the same column with the same letters are not significantly different (DMRT, $P < 0.05$).

3.2 Number of leaves

The number of leaves was not significantly influenced by any interactions: variety x fertilizer x dose (F = 0.724, df = 3, 30, P = 0.545), variety x fertilizer (F = 0.072, df = 1, 30, P = 0.863) and fertilizer x dose (F = 2.473, df = 3, 30, P = 0.081). Only the dose factor had a significant effect on the number of leaves (F = 5. 727, df 3, 30, P = 0.0030 (Fig. 1). Considering urea, the highest number of leaves for Boyo landrace was 55, from 4 g treatment, followed by 39 and 38 from 2 g and 6 g, respectively (Fig. 1a). The highest number of leaves for Adamawa landrace was 54 from 4 g treatment. This was followed by 46, 42 and 40 from 6 g, 0 g and 2 g, respectively (Fig. 1a0. Considering ammonium sulphate, the 4 g (54) and 6 g (54) treatments produced the highest number of leaves, which were significantly different ($P <$ 0.05) from those produced by 2 g (27) and 0 g (27) for Boyo landrace (Fig. 1b). For the Adamawa landrace, the pattern was similar to Boyo, with 4 g (56) and 6 g (530 producing more leaves that 2 g (32) and 0 g (29) (Fig. 1b).



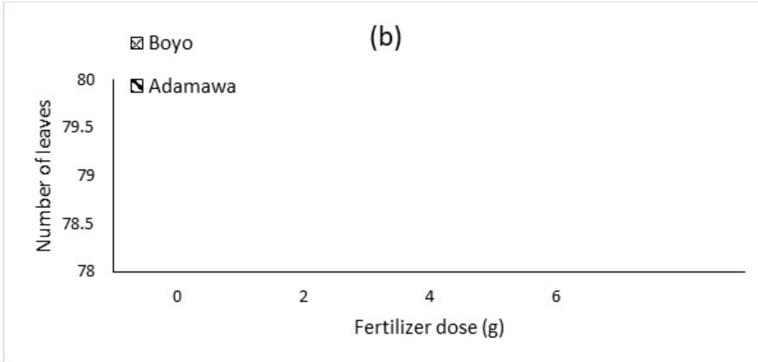
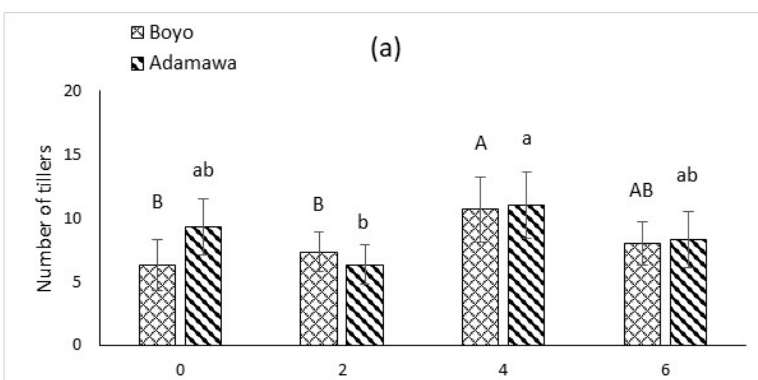


Figure 1. Effect of fertilizer types and doses on number of leaves of two Cameroon wheat landraces. (a) – effect Urea and (b) effect of ammonium sulphate. Uppercase letters compare means within the Boyo landrace per fertilizer type. Lowercase letters compare means within the Adamawa landrace. Means with the same letter in the same graph are not significantly different (DMRT, $P < 0.05$).

3.3. Number of tillers

The number of tillers of Boyo and Adamawa landraces are presented in figure 2. There was no significant interaction effect: variety x fertilizer x dose (F = 0.999, df = 3, 30, P = 0.407), variety x fertilizer (F = 0.446, df = 1, 30, P = 0.509), variety x dose (F = 0.634, df = 3. 30, P = 0.599), and fertilizer x dose (F = 2.616, df = 3, 30, P = 0.069). however, the dose effect significantly influenced the numbers of tillers (F = 7.849, df = 3, 30, P = 0.001). For the Boyo landrace, the highest numbers of tillers for urea was 11 from 4g, followed by 8 from 6g and 2g (Fig. 2a). For the Adamawa landrace, the highest numbers of tillers with urea was 11 from 4g, followed by 8 from and 7 from 6g and 2g, respectively (Fig. 2a).

For ammonium sulphate, the number of tillers varied significantly according to dose for the Boyo landrace (F = 3.808, df = 3, 8, P = 0.050). the highest number of tillers was 13, from 6g of ammonium sulphate. This was followed by 10 and 6 from 4g and 2g, respectively (Fig. 2b). for the Adamawa landrace, the highest tiller numbers were 12 and 9, from 4g and 6g of ammonium sulphate, respectively, and they differed significantly (F = 5.436, df = 3, 8, P = 0.025) from 6 and 3 tillers produced by 2g and the control, respectively (Fig. 2b).



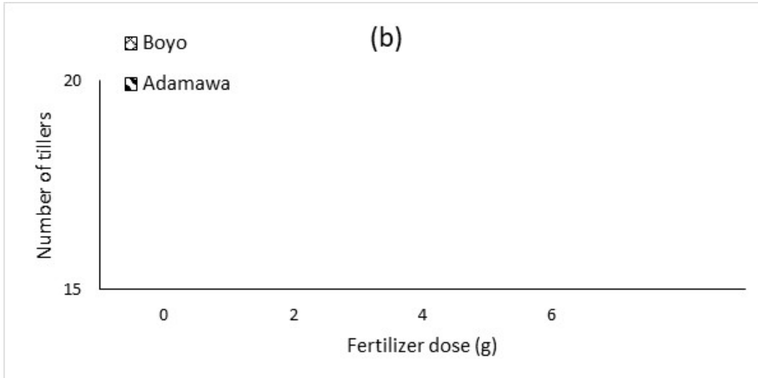


Figure 2. Effect of fertilizer types and doses on number of tillers of two Cameroon wheat landraces. (a) – effect Urea and (b) effect of ammonium sulphate. Uppercase letters compare means within the Boyo landrace per fertilizer type. Lowercase letters compare means within the Adamawa landrace. Means with the same letter in the same graph are not significantly different (DMRT, $P < 0.05$).

3.4 Number of spikes

There was no significant interaction effect for variety x fertilizer x dose (F = 2.256, df = 3, 30, $P = 0.102$) and fertilizer x dose (F = 1.570, df = 3, 30, $P = 0.217$). However, some interaction effects were significant: variety x fertilizer (F = 4.362, df = 1, 30, $P = 0.045$) and variety x dose (F = 3.644, df = 3, 30, $P = 0.024$). for the Boyo landrace with the use of urea, the highest number of spikes was 7, from 4g, followed by 6 from 6g and 2g (Table 2). Similarly, the highest number of spikes was 6, from 4g of urea for the Adamawa (Table 2).

Figure 2 : Sampling map

For the ammonium sulphate at 6g, the Boyo landrace produced 10 spikes, followed by 7 from 4g. Adamawa landrace produced 4 spikes from 6g and 4g pf ammonium sulphate, followed by 2 spikes from 0 g (Table 2).

Table 2. Number of spikes from varieties wheat and different fertilizers.

Dose (g)	Urea		Ammonium Sulphate	
	Boyo	Adamawa	Boyo	Adamawa
0	3.0 ± 0.57ab	6.0 ± 2.52a	3.0 ± 0.58c	2.0 ± 0.57a
2	6.0 ± 3.00ab	4.0 ± 2.08a	4.0 ± 0.57bc	4.0 ± 1.16a
4	7.0 ± 0.57a	6.0 ± 1.53a	7.0 ± 1.53b	4.0 ± 2.08a
6	6.0 ± 2.65ab	5.0 ± 2.08a	10 ± 2.31a	4.0 ± 2.08a

Means (± standard deviation) within the same column with the same letters are not significantly different (DMRT, $P < 0.05$).

3.5. Length of spike

Many interaction effects did not significantly affect the length (cm) of the spikes: variety x fertilizer x dose (F = 0.347, df = 3, 30, $P = 0.231$), and variety x dose (F = 1.211, df = 3, 30, $P = 0.306$). nevertheless, the interactions between fertilizer x dose was significant (F = 314.245, df = 3, 30, $P = 0.001$). As shown in Table 3, the length of spikes did not differ for the Boyo landrace with urea. Also, for the Adamawa landrace, the spike length from 4g (10.27cm), 2g (10.17cm) and 6g (9.70cm) of urea were not significantly higher than that of the control (9.70cm) (Table 3).

For ammonium sulphate, the highest spike lengths for Boyo landrace were recorded from 6g (10.30cm) and 2g (10.44cm) (Table 3). A similar trend was observed for the Adamawa landrace with 4g, 2g and 6g producing 10.23cm, 10.53cm and 9.93cm, respectively (Table 3).

Table 3. Length (cm) of spikes from varieties wheat and different fertilizers.

Dose (g)	Urea		Ammonium Sulphate	
	Boyo	Adamawa	Boyo	Adamawa
0	10.49 ± 0.99a	9.70 ± 1.25a	8.13 ± 1.25b	7.80 ± 1.37b
2	10.07 ± 1.03a	10.17 ± 0.77a	10.44 ± 2.48a	10.53 ± 0.93a
4	10.23 ± 1.18a	10.27 ± 1.11a	9.89 ± 1.18a	10.23 ± 0.94a
6	10.26 ± 0.71a	9.70 ± 0.82a	10.30 ± 1.22a	9.93 ± 1.07a

Means (± standard deviation) within the same column with the same letters are not significantly different (DMRT, $P < 0.05$).

3.6. Number of spikelets

The spikelet number was not influenced by any interaction effect: variety x fertilizer x dose (F = 0.842, df = 3, 224, P = 0.472), variety x fertilizer (F = 1.477, df = 1, 224, P = 0.226), variety x dose (F = 0.461, df = 3, 224, P = 0.710) and fertilizer x dose (F = 0.279, df = 3, 224, P = 0.841). For the different urea doses, the number of spikelets for the Boyo landrace was 17 for all (Table 4). The value was also 17 for all doses of urea for the Adamawa landrace (Table 4). For the ammonium sulphate doses on Boyo, the number of spikelets was 16 for all (Table 4). The value was 17 for all doses of the ammonium sulphate on Adamawa landrace (Table 4).

Table 4. Number of spikelets from varieties wheat and different fertilizers.

Dose (g)	Urea		Ammonium Sulphate	
	Boyo	Adamawa	Boyo	Adamawa
0	17.0 ± 2.12a	17.0 ± 3.34a	16.0 ± 1.70a	17.0 ± 1.99a
2	17.0 ± 1.78a	17.0 ± 2.63a	16.0 ± 1.60a	17.0 ± 3.61a
4	17.0 ± 2.75a	16.0 ± 2.40a	16.0 ± 2.72a	17.0 ± 2.82a
6	17.0 ± 2.37a	17.0 ± 1.85a	17.0 ± 2.53a	16.0 ± 2.71a

Means (± standard deviation) within the same column with the same letters are not significantly different (DMRT, $P < 0.05$).

3.7. Number of grains

Interaction effects for variety x fertilizer x dose, and variety x dose were not significant ($P > 0.05$). However, the interaction effects of variety x dose was significant (F = 7.162, df = 3, 40, P = 0.001) on the number of grains as well as variety effect (F = 30.084, df = 1, 40, P = 0.001) and dose (F = 39.225, df = 3, 40, P = 0.001) (Fig. 3). For urea on Boyo landrace, the number of grains ranged from 331 from 6g of urea to 154 grains from the control (Fig. 3a). For the Adamawa landrace, the number of grains was 320, 313, and 307 from 2g, 4g and 6g of urea, respectively (Fig. 3a).

Using Ammonium sulphate, the highest number of grains for the Boyo landrace was 337, from 6g, followed by 282 and 232 from 4g and 2g respectively (Fig. 3b). For Adamawa landrace, 2g and 4g of ammonium sulphate produced the highest number of grains at 449 and 448. This was followed by 6g at 403 grains (Fig. 3b).

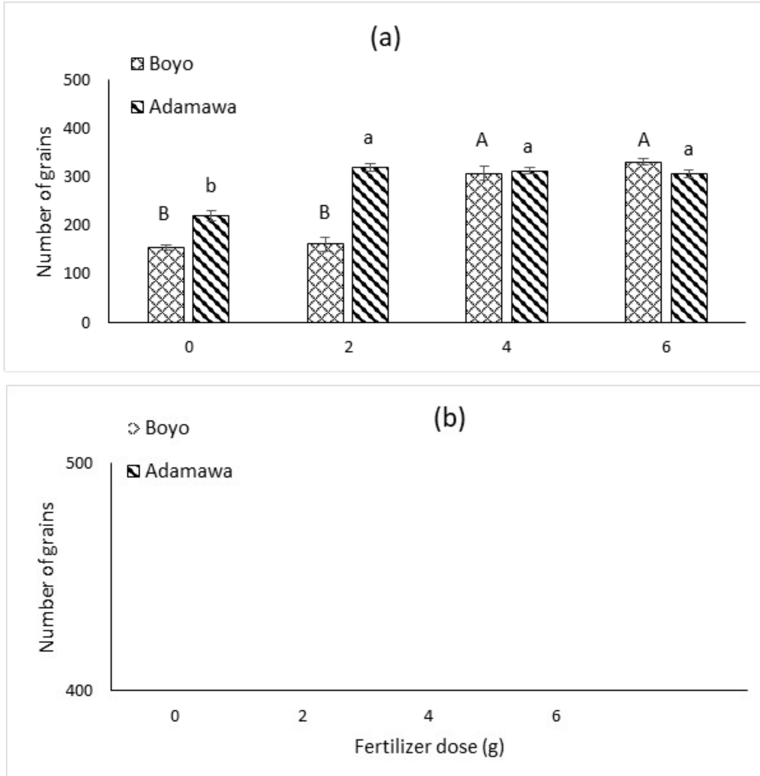


Figure 3. Effect of fertilizer types and doses on number of grains of two Cameroon wheat landraces. (a) – effect Urea and (b) effect of ammonium sulphate. Uppercase letters compare means within the Boyo landrace per fertilizer type. Lowercase letters compare means within the Adamawa landrace. Means with the same letter in the same graph are not significantly different (DMRT, $P < 0.05$).

3.8. Weight of grains

Analysis revealed that the fresh weight of grains was affected only by the variety x dose interaction effect ($F = 4.40$, df = 3, 40, $P = 0.009$). no other interaction had any effect on the fresh weight of grains. Fresh grain weight was significantly influenced by variety ($F = 20.651$, df = 1, 40, $P = 0.0001$) and dose ($F = 28.467$, df = 3, 40, $P = 0.0001$).

For the Boyo landrace on urea treatments, the fresh grain weight ranged from 182.02g rom 6g to 82.96g from the control (Table 5). The fresh grain weight for 2g and 4g urea were 101.15g and 165.53g, respectively, for Boyo landrace. For the Adamawa landrace using urea, the fresh grain weight was 174.72g, 170.72g and 160.77g from 2g, 4g and 6g of urea, respectively (Table 5).

Using ammonium sulphate, Boyo landrace produced the highest fresh grain weight at 191.37g from 6g. this was followed by fresh weight of 179.51g and 110.90g from 4g and 2g of ammonium sulphate, respectively (Table 5). The Adamawa landrace produced fresh grain weight of 258.15g and 249.89g, from 4g and 2g of ammonium sulphate. This was followed by 236.74g from 6g (Table 5).

Table 5. Fresh grain weight (g) from different varieties of wheat and different fertilizers.

Dose (g)	Urea		Ammonium Sulphate	
	Boyo	Adamawa	Boyo	Adamawa
0	82.06 ± 2.27c	130.56 ± 9.21b	53.73 ± 4.2c	50.69 ± 1.66c
2	101.15 ± 10.90b	174.72 ± 7.44a	110.90 ± 5.64b	249.89 ± 4.39b
4	165.53 ± 11.08a	170.72 ± 7.46a	179.51 ± 3.05a	258.15 ± 18.75ab
6	182.02 ± 12.38a	160.77 ± 8.43a	191.37 ± 2.05a	236.74 ± 9.89a

Means (± standard deviation) within the same column with the same letters are not significantly different (DMRT, $P < 0.05$).

3.9. Gluten content

The gluten content (%) of Boyo ad Adamawa landraces of wheat treated with urea and ammonium sulphate are presented in figure 4. Like fresh grain weight, gluten content was influenced by only the interaction of variety x dose (F = 6.340, df = 3, 40, $P = 0.003$). no other interaction effectively influenced the gluten content. The gluten content was also significantly influenced by variety (F = 13.414, df = 1, 40, $P = 0.021$) and dose (F = 14.921, df = 3, 40, $P = 0.001$). considering urea, the Boyo landrace ranged from 32.65% from 6g to 24.34% from 0g (Fig. 4a). The Adamawa landrace produced the highest gluten content from 6g (52.5%), followed by 2g (44.81%) and 4g (40.86%) (Fig. 4a).

Considering ammonium sulphate, Boyo landrace gluten content ranged from 28.54% from 6g to 24.54% from 0g (Fig. 4b). Similarly, Adamawa landrace produced the highest gluten content at 48.51% from 6g, followed by 40.91% and 40.32g from 2g and 4g, respectively (Fig. 4b).

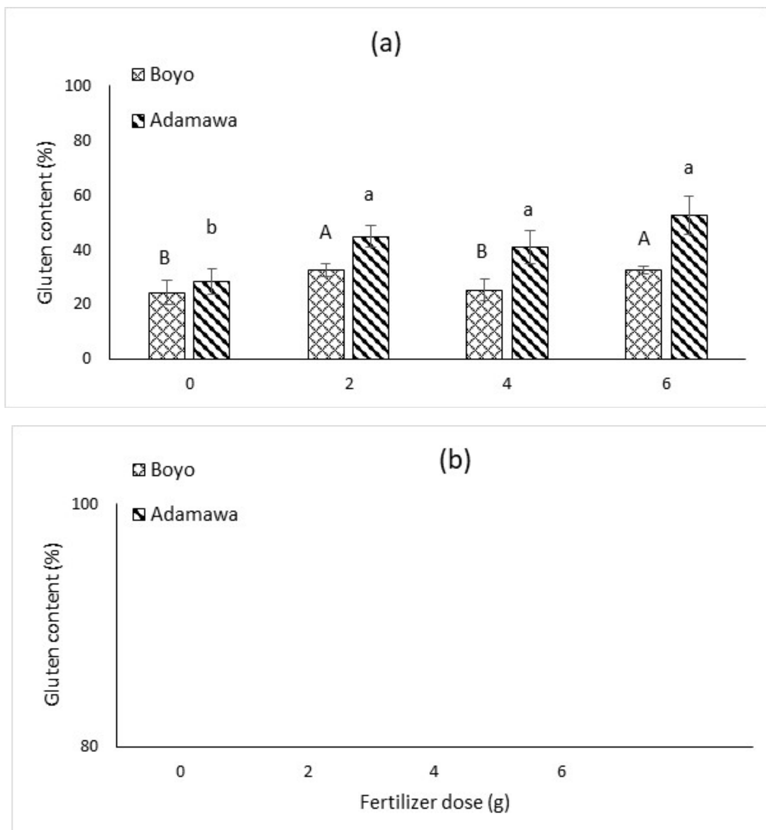


Figure 4. Effect of fertilizer types and doses on gluten content %) of two Cameroon wheat landraces. (a) – effect Urea and (b) effect of ammonium sulphate. Uppercase letters compare means within the Boyo landrace per fertilizer type. Lowercase letters compare means within the Adamawa landrace. Means with the same letter in the same graph are not significantly different (DMRT, $P < 0.05$).

4. Discussion

The results revealed that wheat plant height was not influenced by fertilizer and doses. However, it was observed that the wheat plant height increases with increasing quantity of urea and ammonium sulphate, similarly to many other studies that reported that urea and ammonium sulphate increase wheat plant height (Khursheed and Muhammad, 2015; Zorb et al., 2018; Wilson et al., 2020). It was also observed that Boyo landrace was generally taller than Adamawa landrace irrespective of fertilizer type. This suggest that the wheat plant height for the two landraces is highly influenced by genotype. Adamawa

landrace are adapted for the Adamawa region of Cameroon, which is dry and supports the growth of shorter and dwarf wheat variety, compared to Boyo in the North West Region of Cameroon, which is wet and relatively cold, supporting more vegetative growth such as height. This proposition is supported by Rahimi-Moghaddam et al. (2023). The number of leaves progressively increased with increase in the dose of both fertilizers. In addition, the number of leaves for Boyo from urea and ammonium sulphate at the same dose was similar, suggesting that number of leaves is largely controlled by landrace and fertilizer dose. Khursheed and Mahammad (2015), even though worked on leaf area (cm^2) for two wheat variety *T. aestivum* and *T. durum* treated with urea and ammonium sulphate reported similar results.
Like number of leaves, the number of tillers increased with increased doses of both fertilizers. The pattern was similar for both fertilizers. This finding is in line with the report of Khursheed and Mahammad (2015) who reported the number of tillers per plant of *T. aestivum* and *T. durum* at three from urea and ammonium sulphate. Nevertheless, the current study reported high tiller numbers of up to ten and also as low as three, indicating a close interaction between genotype and fertilizer for the number of tillers (Alan et al., 2007).

For the yield parameters, the number of spikes of the Boyo landrace increased with increase dose of both fertilizers, meanwhile the number of spikes remained relatively constant for each fertilizer type across doses. This suggests that the number of spikes is inherent in the genotype and only slightly controlled by fertilizer. The very observation is reported for the length of the spike and number of spikelets per plant. However, it is important to note that other studies have reported increased in spike number and spikelet number with increased urea and ammonium sulphate (Hafez and Kobata, 2012). Hafez and Kobata (2012) opine that increased in spikelet number with increased urea and ammonium sulphate is due to increased N absorption until anthesis. It should be mentioned that their study had multiple applications of urea an ammonium sulphate, encouraging biomass formation even close to anthesis, while in the current study, only three fertilizer applications were done. The current study with one N source application is on a par with that of Khan et al. (2009) with one urea application at different doses and reported similar spike length.

The analysis also revealed that urea and ammonium sulphate had significant effects on number of grains per spike. The number of grains per spike increased significantly in all urea and ammonium sulphate treatments compared to the control. Similar observations were made by Khan et al. (2009) and Khursheed and Mahammad (2015). It was also observed that both landraces had more grains per spike under ammonium sulphate than under urea. According to Fageria and Gheyi (1999), sulfur present in ammonium sulphate can explain this discrepancy. They posit that sulfur is an important component of some amino acids, coenzymes and all proteins, performing similar functions in plant nutrition to that of N, but in much smaller quantities than N. The increased number of grains per spike translated into increased grain fresh weight. Increased grain weight of wheat with increase N – fertilization is well documented (Khan et al., 2009; Giambalvo et al., 2010; Ramirez-Wong et al., 2014; Khursheed and Mahammad, 2015). It was also observed that both landraces performed better in ammonium sulphate compared to urea for fresh grain weight, an observation similar to that of Khan et al. (2009) and Giambalvo et al. (2010).

The gluten content obtained from wheat followed a similar pattern to that of fresh grain weight.

Gluten content increased with increase fertilization with urea and ammonium sulphate, as reported by others (Ejaz et al., 2002; Giambalvo et al., 2010; Ramirez-Wong et al., 2014; Khursheed and Mahammad, 2015; Horvat et al., 2021; Yang et al., 2022; Cui et al., 2023). The increased gluten content could be explained because increased urea and ammonium sulphate fertilization provide available N for the synthesis of amino acids needed for protein synthesis and eventually increase gluten content (Ejaz et al., 2002; Ramirez-Wong et al., 2014; Cui et al., 2023). Gluten protein content accumulation in wheat grains during filling is greatly influenced be environmental conditions such as N availability and genetics (Wieser and Seilmeier, 1998; Malik et al., 2013; Garcia-Molina and Barro, 2017). Since gluten content were higher in Adamawa than in Boyo for both fertilizers and corresponding doses, it could be indictive of Adamawa's superiority over Boyo for gluten accumulation.

5. Conclusion

The current study led to three main conclusions. First, some growth parameters of the two wheat landraces, Boyo and Adamawa are influenced principally by genotype and others by an interaction between the genotype, fertilizer type and doses. Second, the yield of wheat was higher for both varieties under ammonium sulphate compared to urea, and third, the gluten content for both Boyo and Adamawa landrace did not differ but increased with increased urea and ammonium fertilization. It is recommended that both landraces be cultivated in Bambili with preference under ammonium sulphate at 6 g per plant. Further study is suggested in areas of optimal N need, irrigation and the role of pest and disease in this ecological system.

6. Conflicting interest

The authors declare no competing interest.

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