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Agro-Morphology Evaluation and Gluten Content Estimation of Wheat (*Triticum aestivum* L.) in the Western Highland of Cameroon

Liliane Ngoune Tandzi[1*], Aminatou Fanche Mongoue[2], Eddy Leonard Mangaptche Ngonkeu[2,3]

[1]Department of Crop Production Technology, College of Technology, University of Bamenda, Bambili, Cameroon
[2]Institute of Agricultural Research for Development (IRAD), Yaoundé, Cameroon
[3]Department of Plant Biology and Physiology, University of Yaoundé I, Yaoundé, Cameroon
Email: *tnliliane@yahoo.fr

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Abstract

Agriculture is amongst the major occupations in Cameroon where over 70% of citizens are involved and it contributes enormously to the economy of the country. Wheat is one of the most consumed cereals in Cameroon with very high importation rate. However, the adoption of wheat production in the cropping system could have the potential to pull farmers out of poverty. It is essential in human foods and animal feeds. This study aims to investigate on the adaptability of wheat varieties based on growth traits and yield as well as to estimate the gluten content in each of the tested variety in the North-West region. Eight wheat varieties (five from CIMMYT, two from IRAD and one local variety) were evaluated in a factorial design with two types of fertilization (organic and inorganic), in two site (Santa and UBa farm) and five environments. Agro-morphological data were collected and were subjected to the analysis of variance using R software. The gluten content related to the baking quality of wheat flour was estimated per tested variety. Highly significant differences were observed among varieties, sites, environment and fertilization for all parameters estimated. The general mean of all the traits evaluated was significantly higher when using organic fertilizer than inorganic, meaning that the application of organic fertilizer provides better performance of wheat growth. The elevated number of tillers found in Santa could inform on the high level of soil fertility for wheat production in that area. Environment 1 was found to be the best follow by environment 3 and 5. IRAD I gave the highest yield followed by Alexander Wonder and IRAD II. 11SATYND and 29SAWYT were promising introduced varieties in term of grain weight when using organic fertilization. Wet and dry gluten yield varied from 3.8 (ALEXANDER Wonder) to 5.5 (IRAD I) and from 3.7 (IRAD II) to 7.9 (IRAD I) respectively. All the introduced wheat varieties expressed low wet and dry gluten yield as compare to the check Amigo. IRAD I was the best variety to be produced for industrial purposes taken into account the high level of gluten content. IRAD I, 42ESWYTB and IRAD II were found to have their moisture content percentage of flour below that of the check (Amigo) and therefore could be recommended for manufactured foods.

Keywords

Wheat, Environment, Variety, Production, Gluten, Nutrition

1. Introduction

Agriculture is amongst the major occupations in Cameroon where over 70% of citizens are involved [1] and it represents the backbone of the economy of the country [2]. Local production in agricultural sector is responsible for providing food security to both rural and urban populations in the country. Based on its agro-ecological diversity (five agro-ecological zones), Cameroon has great potentials for agricultural production thus contributing towards feeding over 23 million people and beyond. An estimated 45% of Cameroon's gross domestic product (GDP) depends on Agriculture [3]. Yet, most farmers still depend on the use of out dated tools such as hoes, cutlasses, spades and traditional agricultural techniques (manual weeding, hoeing and harvesting). Approximately 6% of the industrious population practice livestock farming [1]. Despite the huge potential of the agricultural sector especially in agribusiness sector for Africa's economic wellbeing, much needs to be done to optimize profits [4]. It has been reported that Africa's agricultural sector is still performing below standard when compared with other continents in terms of productivity, agricultural mechanization, advisory, extension services, access to credit and finance [5]. Until the late 80s, Cameroon was self-sufficient in agricultural production and was able to export food to the neighboring countries. Since early 90s, Cameroon started spending billions of francs CFA in the importation of large quantities of food including wheat in various forms [1].

Wheat (*Triticum aestivum* L.) belongs to the grass family Poaceae (Gramineae) and is the first important and strategic cereal crop for the majority of world's population [6]. Wheat is a temperate climate crop, sensitive to high temperatures: for every 2˚C rise in the daily temperature above 18˚C, the potential yield of wheat diminishes by about 10% [7].

Wheat is the most consumed and imported cereal in Cameroon. It is considered to be a crop of mass consumption rate which is grown in three ecological zones of the country. Even though the Cameroon climatic zones are favorable for wheat production, between 2000 and 2019, 0.84 thousand metric tonnes of wheat were produced annually in Cameroon whereas an average of 513.85 thousand metric tonnes were imported annually [4]. This is very poor compared with the production of other African countries which could be attributed to lack of knowledge by the local population, lack of appropriate agricultural inputs, variation in climatic patterns, lack of high yielding, diseases resistant and well adapted varieties as well as post-harvest management facilities [1].

In 2021, reports indicated that wheat production in Cameroon stands at very negligible amounts or 0 thousand tons including the previous 5 years with importation requirement of 841,000 tons of wheat. About 93% of wheat importation is used for food and the rest for non-food or feed consumption [8]. According to Mbodiam [9], Cameroon imported 860,000 tons of wheat in 2020 amounting to about XAF150 billion. Though, the environmental conditions in Cameroon are favorable for wheat cultivation [10]. Unfortunately, despite increasing demand for wheat, high expenditure with importation and the fact that Cameroon has favorable conditions, production levels have been observed to remain low. One of the major constraints to wheat production in the country could be the failure in the adoption of wheat crop by farmers and the lack of wheat insertion in their cropping systems.

Nowadays, nutritional modification of food products (combination, fermentation and germination) has gained attraction due to the increased of consumer interest in healthy foods. Wheat is essential in human nutrition and the grain is rich in nutrients such as minerals, protein (8% - 16%), fat (1% - 3%) and fibre (12% - 15%) [11]. The properties of wheat that are ideal for processing into different food products have been greatly improved especially in detailed research on storage proteins which constitute the gluten [12]. The classical definition of gluten is related to the baking quality of wheat flour and it is made up of two functionally distinct groups of storage proteins known as monomeric gliadins and polymeric glutenins [13]. The quality control of wheat flour is of fundamental importance to guarantee the necessary adjustments in the processes due to the natural variations of wheat. To obtain flour, clean and conditioned wheat is reduced using a multi-stage process of successive milling with corrugated and smooth rollers, sieving and purification. At each step, an amount of flour is produced, removed and subsequently combined in proportions to form the desired flour [14]. Gluten helps dough rise by trapping gas bubbles during fermentation. The transformed wheat products can serve as relief for malnutrition. Nasir *et al.* [15] concluded that 9% and 10% moisture content is suitable for storage stability and longer shelf life of wheat flour. Li *et al.* [16] found that as storage time of fresh wet noodles increased, the springiness gradually decreased, but the hardness increased and the cooking loss rate increased obviously, with the decreased of water absorption rate. Baek *et al.* [17] reported that the use of low gluten content of wheat flour provide a safe and tasty option for consumers with dietary needs.

The low rural income levels of farmers in the study region, coupled with the demands of applying chemical fertilizers, often represent a barrier to their acquisition. In this context, the application of organic fertilization should offer an appropriate solution for restoring soil fertility while ensuring high productivity. Therefore, there is much to be done to meet with wheat production levels to fully satisfy populations demand. The objective of this work was to investigate the adaptability of wheat varieties based on growth traits and yield in the North West region of the country as well as to estimate the gluten content of each of the tested variety.

2. Materials and Methods

2.1. Experimental Sites and Environments

This research project was carried out two times (two seasons) from August to December 2022 and from March to August 2023 in the Western Highlands Agro-ecological zone of Cameroon. The first experimental site was at the University of Bamenda, precisely at COLTECH demonstration farm. The University of Bamenda is located in Tubah Sub Division of the North West Region of Cameroon. It is at some 10km North East of Bamenda city. The latitude and longitude are 6.0N/10.0E with an altitude of 1600m above sea level [18].

Then, another experiment was conducted in Santa at the Mbei village precisely in the demonstration plot of the Agric post Santa, one of the Sub-divisions in Mezam Division of the North West Region of Cameroon. It is located between latitudes 5˚42' and 5˚53' north of the equator and longitudes 9˚58' and 10˚18' east of the Greenwich Meridian 5. The mean annual temperature of the area varies from 21.8˚C to 30.8˚C. Its annual rainfall is between 2000 - 3000 mm and rainy season starts from March to September and dry season from October to February.

The varieties were evaluated in five environments defined in **Table 1**.

Table 1. Various environments used for testing.

No.	Environment
1	Santa (site) + 2023 (year)
2	UBa1 (site)+ 2022 (year)
3	UBa2 (site) + 2022 (year)
4	UBa1 (site) + 2023 (year)
5	UBa2 (site) + 2023 (year)

2.2. Plant Materials

Eight wheat varieties were used among which five were coming from CIMMYT (International Maize and Wheat Improvement Centre), two from IRAD (Institute of Agricultural Research for Development) and one local check used as control (Table 2).

Table 2. List of wheat varieties evaluated.

No.	Variety	Origin
1	29SAWYT	CIMMYT
2	20HTWYT	CIMMYT
3	42ESWYT	CIMMYT
4	12HZWYT	CIMMYT
5	11SATYNDRGT	CIMMYT
6	IRAD I	IRAD
7	IRAD II	IRAD
8	ALEXANDER WONDER	CHECK

2.3. Experimental Design, Planting and Field Management

The experiment was laid out in a randomized complete block design (RCBD) arranged in a factorial way with two replicates using two type of fertilization (poultry manure and N-P-K 20-10-10). Planting was done on the 14th of August 2022 and on the 20th of March 2023 at the COLTECH experimental farm whereas in Santa, it was done on the 22 of March 2023.

The first weeding operation was done 4 weeks after planting and continuously done every after 2 weeks. The field was sprayed with cypercot or greforcet a systemic insecticide and Pencozeb 80WP a contact fungicide against insects and fungi pests respectively. Head blight also called *Fusarium* head blight caused by *Fusarium spp* was suppressed with the application of a cupper fungicide (Nordox 75WG) at the disease incidence level. The spraying interval was twice a week during moments of high rain intensity, once a week for moderate intensity and once in two weeks during dry spells periods. The field was also covered by mosquito net to prevent pests like birds from eating the produce at the milky stage.

2.4. Data Collected

Data were collected on emergence rate, plant height, leaf length, number of leaves, number of tillers and grain weight. The quality parameter was recorded on the 8 wheat cultivars and a locally sold wheat flour (Amigo flour) was used as check. The wet and dry gluten percentage was obtained using the protocol describes by AACCI official method [19] and Schultz [20]. The wet and dry gluten percentage were estimated using the following equations:

$$\text{Wet Gluten } \% = \frac{A}{C} \times 100$$

$$\text{Dry Gluten } \% = \frac{B}{C} \times 100$$

where: A = Weight of Wet gluten content (g); B = Weight of Dry gluten content (g); C = Weight of the flour (g).

Wet gluten yield and dry gluten yield were estimated using the following formula:

$$\text{Wet gluten yield} = \frac{\text{Weight of wet gluten}}{\text{Weight of wet flour}}$$

$$\text{Dry gluten yield} = \frac{\text{Weight of dry gluten}}{\text{Weight of dry flour}}$$

The moisture content was estimated using the following formula [21]:

$$\text{Moisture content} = \frac{(\text{weight of wet gluten} - \text{weight of dry gluten})}{\text{weight of wet gluten}} * 100$$

2.5. Data Analysis

The analysis of variance (ANOVA) for various parameters collected was conducted using appropriate statistical software (R). The means were separated using Turkey test at 0.05 level of probability and presented in tables and charts.

3. Results

3.1. Analysis of Variance

Highly significant differences (at 0.1% probability) were observed among varieties, environment and fertilization for all parameters collected (**Table 3**). Some two-way and three-way interactions expressed also significant differences at 5%, 1% and 0.1% probability whereas others were non-significant. The results indicated that the factors analysed and some of their interactions, affected the parameters studied at various levels. This means that the varieties have different potentials which can be expressed more easily if the soil is amended in the appropriate way. These results were similar with the findings of Ndjadi *et al.* [7] and Darwish *et al.*, [22].

Table 3. Mean square of traits collected per type of fertilization, site, environment.

Source of variation	Df	Emergence	No. of leaves	No. of tillers	Plant height	Gain weight	Leaf length
Environment	4	5205***	77.3***	191.7***	29,441***	6265***	5726***
Variety	7	612***	4.8***	11.5***	4926***	2417***	633***
Fertilization	1	2409***	21.3***	72.1***	13,941***	11,883***	14,579***
Variety:Fertilization	7	203NS	0.4NS	1.2NS	153NS	496***	123***
Variety:Environment	28	270***	1.2***	5.4***	834***	1046***	140***
Fertilization:Environment	4	965***	7.0***	31.2***	1989***	1083***	779***
Variety:Fertilization:Environment	28	201**	0.5NS	1.3NS	72NS	375***	154***
Error	80	328.8	1.1	4.1	576	554	370

*** = highly significant at 0.1%; ** = highly significant at 1%; * = significant at 5%; NS = non-significant at 5% probability level; DF = degrees of freedom.

3.2. General Effect of Fertilization on the Estimated Parameters

The general mean of all the traits evaluated was significantly higher when using organic fertilizer than inorganic, meaning that the application of organic fertilizer provides better performance of wheat plant (**Figure 1**). These results were different from that of Ndjadi *et al.* [7] who found that the application of organic amendments in combination with chemical fertilizers tends to increase crop yield in comparison to plots where the same fertilizers are used in isolation.

Figure 1. General mean performance of varieties per type of fertilization for parameters collected.

3.3. General Performance of Estimated Parameters per Experimental Site

The general mean performance of the traits collected on the tested varieties was higher in Santa than Experimental farm of the University of Bamenda when using organic and inorganic fertilizer (**Figure 2**). This result revealed that wheat plant performed better in Santa than UBa.

Zheng *et al.*, [23] found in their study that the significantly increases of maximum tiller number, tillering capacity and spike formation rate can be attributed to the improved soil nutrients, since soil nutrients can regulate wheat tillering therefore expressing high level of soil fertility. In the current study, the general mean of tillers (7.5) in Santa was superior to that of UBa (2.7) meaning that Santa soil could be more fertile as compare to that of UBa.

3.4. General Performance of Estimated Parameters per Site and Environment

Among the five environments used in this study, environment 1 was found to be the best follow by environment 3 and 5 based on grain weight, number of tillers

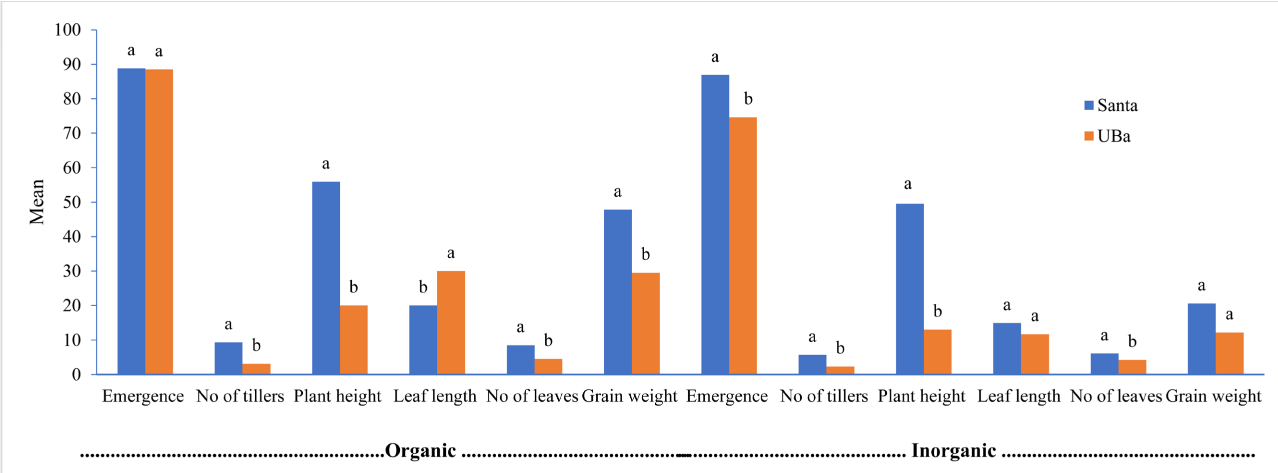

Figure 2. General mean performance of varieties per tested site for parameters collected.

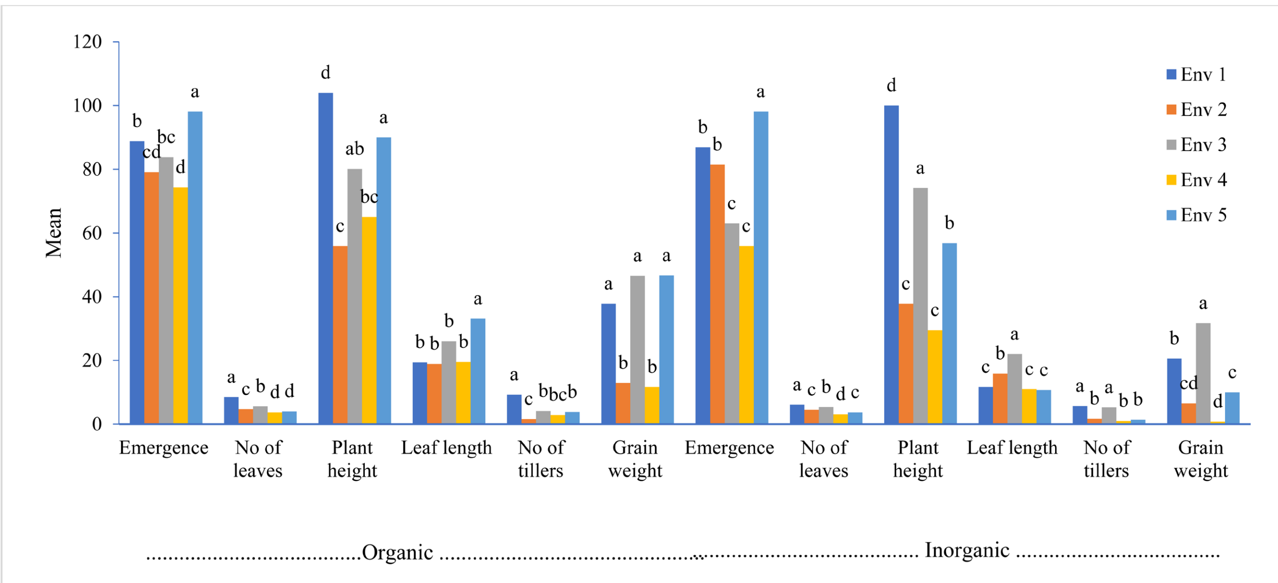

Figure 3. General mean performance of varieties per environment for parameters collected.

and plant height in organic fertilization (**Figure 3**). Plant emergence rate was higher in environment 5 than the rest. This result was different from the finding of Pireivatlou *et al.* [24] who stated that the average grain numbers per spike of wheat genotypes were similar in all their study environments. These differences could be due to the variances in agro-ecological factors involved in the study environments.

IRAD I gave the highest yield followed by Alexander Wonder and IRAD II (**Figure 3**). Similar result was obtained by Tatang *et al.* [25] in their study when using IRAD I in the Western Highlands of Cameroon.

4. Performance of Varieties Evaluated across Environments

4.1. Grain Weight of Tested Varieties across Environments

The type of fertilization showed significant effects on the yield of the varieties.

IRAD I, IRAD II and Alexander Wonder were found to be the best based on grain weight (**Figure 4**). 11SATYND and 29SAWYT were promising introduced varieties in term of grain weight when using organic fertilization. The use of organic fertilizer gives better yield in wheat production than inorganic.

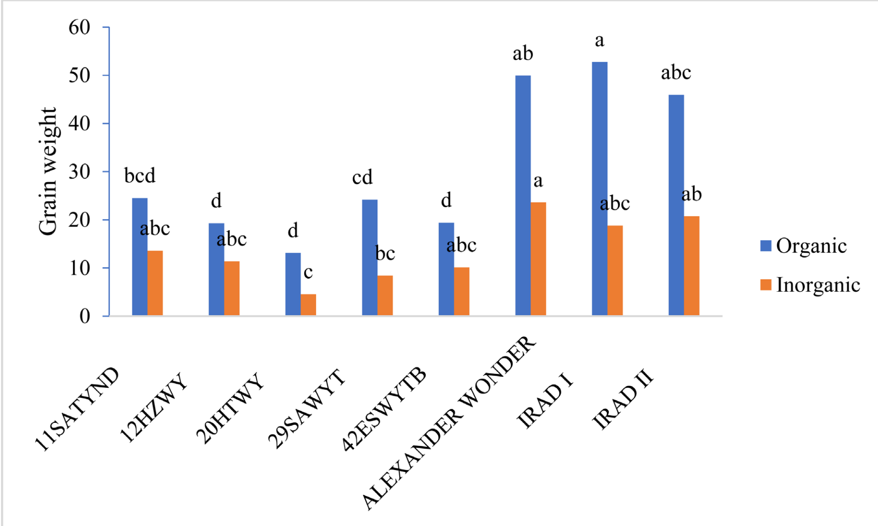

Figure 4. Grain weight of varieties evaluated across environments.

Shillie *et al.* [4] in their study concluded that Cameroon should engage heavily in local wheat production given that the agro-ecological conditions are favourable for wheat production. Therefore, there is a need of stimulating farmer behavior on wheat production by making available the seeds of the best high-yielding wheat varieties (IRAD I, IRADII and Alexander Wonder) identify in the current study.

4.2. Gluten Yield of the Tested Varieties

Wheat is regularly used in human daily diet in the form of wheat flour. Gluten is a major protein present in wheat. It is the protein part of wheat flour which gives elasticity and strength to dough. In the current study, wet and dry gluten yield varied from 3.8 (ALEXANDER Wonder) to 5.5 (IRAD I) and from 3.7 (IRAD II) to 7.9 (IRAD I) respectively (**Table 4** and **Figure 5**). The check wheat flour (Amigo) gave wet and dry gluten yield of 4.7 and 4.6 respectively. All the introduced wheat varieties expressed low wet and dry gluten yield as compare to Amigo (**Figure 5**).

Among the gluten-containing cereals only wheat contains gluten that converts flour into a cohesive, viscoelastic dough after mixing with water [13]. Wheat with high gluten content is preferred by many food manufacturing industries because glutenin proteins are long chains responsible for the elasticity of dough. However, Bendale *et al.* [21] stated that gluten is responsible for digestive discomfort and was found to be allergic therefore it is necessary to select wheat with less gluten content for consumers with dietary needs. The ratio of glutenin to gliadin in gluten had different effects on the digestive characteristics of wheat flours with different gluten strength [26]. Singh and Singh [27] found that crude protein content of wheat gluten ranged from 60.9% to 89.9%.

Table 4. Gluten content of the tested wheat varieties

Variety	Wet gluten (%)	Wet gluten yield	Dry gluten (%)	Dry gluten Yield	Moisture content (%)
29SAWYT	43.54	4.0	20.93	4.0	51.8
20HTWYT	42.03	4.0	18.33	4.0	56.4
12HZWYT	50.32	4.0	22.63	4.0	55.0
11SNYNDRGTB	48.76	4.0	22.36	4.0	54.1
42ESWYTB	60.20	4.0	32.92	4.0	45.3
IRAD I	54.94	5.5	36.16	7.9	34.2
IRAD II	68.48	4.0	39.48	3.7	42.3
ALEXANDER Wonder	69.94	3.8	33.72	4.0	51.8
Amigo (common flour in the market)	18.32	4.7	8.9	4.6	51.4
General mean	50.73	4.2	26.16	4.5	49.2

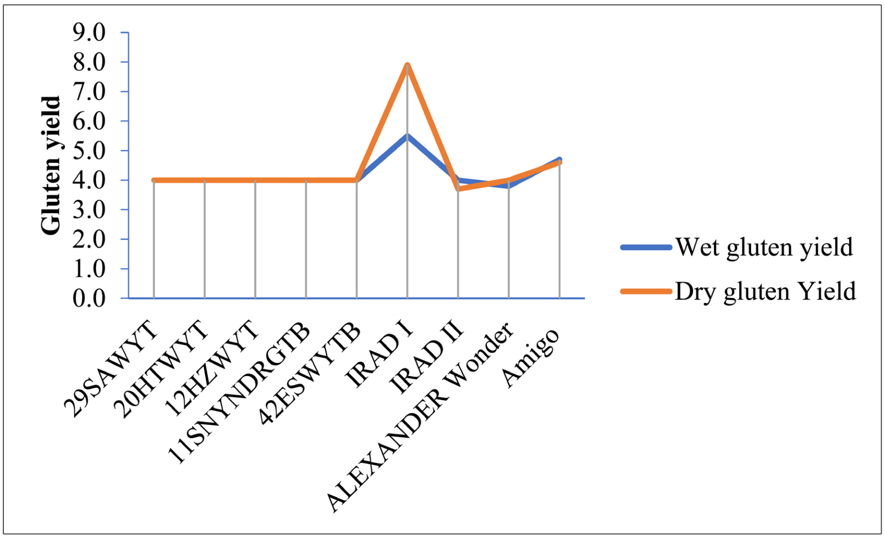

Figure 5. Comparison between Wet and Dry Gluten content.

In the current study, IRADI had high gluten content and can be used for industrial purposes whereas the rest of wheat varieties could be best used for consumption since the gluten yield is less than that of commercial wheat flour Amigo.

4.3. Gluten Percentage and Moisture Content of the Tested Wheat

The wet gluten percentage varied from 18.32 (Amigo flour) to 69.94% (Alexander Wonder) with the general mean of 50.73% (**Figure 6** and **Table 4**). However, dry gluten percentage ranged from 8.9 (Amigo) to 39.48% (IRAD II). The moisture content ranged from 34.2% (IRAD I) to 56.4% (20HTWYT) with a general mean of 49.2%. The commercial flour expressed moisture content percentage of 51.4%. These results were different from the findings of Singh and Singh [27] who reported the wet gluten content varied from 17.8% to 47.23% among their tested wheat genotypes and the dry gluten content varied from 5.9% to 10.1%. The wheat varieties tested were not the same in the two experiments and it could be the cause of the variation observed. It is therefore important to notice that gluten content varies from one variety to another giving the importance of selection. Nasir *et al.* [15] reported that moisture has significant effect on crude protein, crude fat, mould growth and insect infestation: protein and fat content decreased with higher moisture content in wheat flour; mould growth and insect infestation were more in treatments having higher moisture during storage with no infestation in the treatments with lower moisture content (9%). In the present study, IRAD I, 42ESWYTB and IRAD II were found to have their moisture content percentage below that of the commercial flour Amigo and therefore could be recommended for further use.

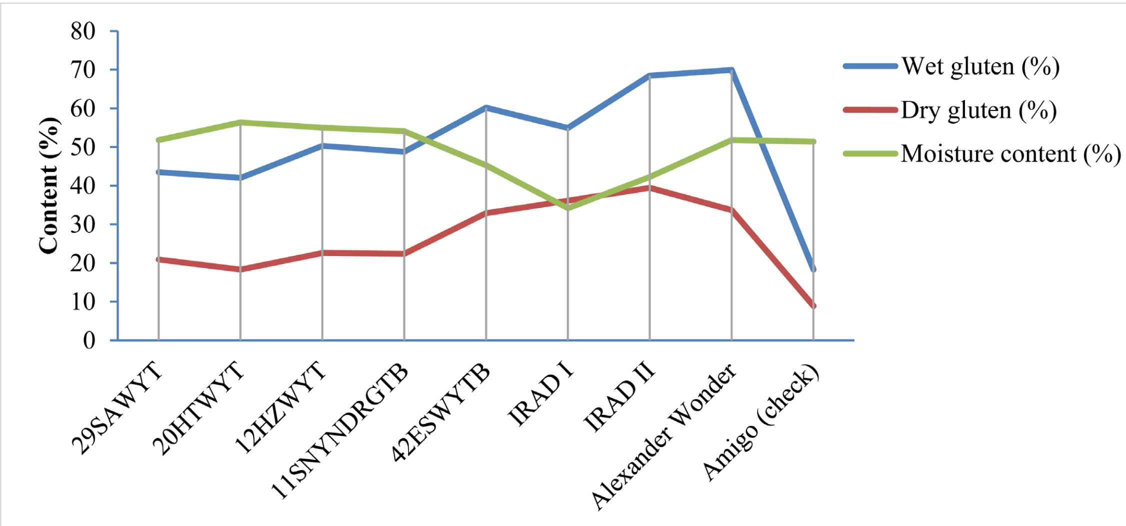

Figure 6. Wet and dry gluten content associated with moisture content in the tested wheat varieties.

5. Conclusion

IRAD I, IRAD II, and Alexander Wonder were found promising wheat varieties to be promoted in the study area. 11SATYND and 29SAWYT are potentials introduced wheat variety to be tested for further use. IRAD I is the best variety to be produced for industrial purposes taken into account the high level of gluten content. The high number of tillers found in Santa could inform on the high level of soil fertility for wheat production in that area. IRAD I, 42ESWYTB and IRAD II were found to have their moisture content percentage below that of the check commercial flour (Amigo) and therefore could be recommended for further use.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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