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Variation of Some Agro-Physiological and Biochemical Parameters of Wheat (*Triticum aestivum* L.) Varieties in Response to Nitrogen Fertilizer Rates at Djirataoua in Southern Niger Republic

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Authors' contributions

This work was carried out in collaboration among all authors. Author AMS designed the study, performed the statistical analysis, and wrote the protocol and the first draft of the manuscript. Author OAM revised the manuscript and made substantial improvement. Authors ABM and MZA were involved in the study as supervisor and co-supervisor, respectively. All authors read and approved the final manuscript.

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ABSTRACT

Nitrogen is the most limiting plant nutrient element of soils in Niger. Farmers apply nitrogen to increase yield of cereal crops. A survey conducted at Djirataoua in southern Niger, revealed that wheat growers applied nitrogen fertilizer with less technical knowledge resulting in low response on growth and yield. To produce suitable recommendations to farmers, a field experiment was conducted during two dry seasons (2016/2017 and 2017/2018) at Djirataoua (13°25'59''N, 7°8'12''E). The aim of the study was to determine the optimum level of Nitrogen for highest yield and agro-physiological parameters of wheat varieties. Four Nitrogen levels (0, 100, 150 and 200 kg N ha^{-1}) and four wheat varieties were evaluated in this study. The experiment was laid out in a split plot design with three replications. Data collected on grain yield, chlorophyll, Nitrogen uptake and protein content were subjected to the analysis of variance and mean comparison. The results showed that application of 150 kg N ha^{-1} Nitrogen resulted in highest grain yield (3202 kg ha^{-1}), chlorophyll content (50.9 SPAD) N uptake (72.63 kg ha^{-1}), and protein content (135.5 g kg^{-1}). The wheat varieties were significantly different in these parameters. Reyna-28 and Sokoll/3/ produced higher grain yield and Nitrogen uptake. Higher protein content was observed in Norman and Sokoll/3/. Significant interactions were observed between Nitrogen rates and variety on yield characters, Nitrogen uptake and protein content. The highest grain yield, Nitrogen uptake and chlorophyll content were achieved by interaction of Reyna-28 and Sokoll/3/ with 150 kg N ha^{-1}. Therefore, application of 150 kg N ha^{-1} and using varieties Reyna-28 or Sokoll/3/ is recommended to farmers for maximum grain yield and high protein content.

Keywords: Wheat; nitrogen; yield; N-uptake; chlorophyll, protein content.

1. INTRODUCTION

"Wheat is one of the world's oldest and most widely used food crops. Wheat plays a particularly crucial role in ensuring global food/nutrition security and supplying a ffth of global food calories and protein" (Reynolds and Braun, 2023). "Wheat is the third major grain crop, and more than 760 million metric tons of wheat are grown on 200 million hectares annually providing around 19% of calories and 21% of protein for mankind" (FAO, 2022). It supplies 18.3% of all calories and 19.8% of proteins in all food consumed (Asmund, 2016).

"Nitrogen (N) is an essential nutrient for crop growth. It improves crop quality and increases productivity and production of agriculture" (Derara et al, 2024). "Nitrogen is often the most deficient of all the plant nutrients. It plays a vital role in all living tissues of the plant. High nitrogen supply favours the conversion of carbohydrates into proteins, which in turn promotes the formation of protoplasm" (Arnon, 1972). "Wheat is very responsive to nitrogen fertilization and very sensitive to insufficient nitrogen" (Cutts and Pauly, 2001). "The most important role of N in the plant is its presences in the structure of protein, the most important building substances from which the living material or protoplasm of every cell is made" (Cutts and Pauly, 2001). "Nitrogen fertilization significantly affected chlorophyll content in leaves and stems. Close positive correlation was observed between grain yield and wheat plant chlorophyll content and average nitrogen concentration" (Ilze and Ruza 2017). "Chlorophyll enables the plant to transfer energy from sunlight by photosynthesis" (Cutts and Pauly, 2001). Therefore, the nitrogen supply to the plant will influence the amount of protein, protoplasm and chlorophyll formed. In turn, this influences cell size and leaf area, and photosynthetic activity (Cutts and Pauly, 2001). According to Riley *et al.*, (2001) "high Nitrogen levels can also harm crops by making wheat plants more vulnerable to lodging, causing both damages to the environment through leaching and nitrate volatilization" (Ma *et al.*, 2010) and economic losses to farmers, because only 33% of all nitrogen fertilizers applied to cereal crops are absorbed in harvested grains (Raun and Johnson, 1999). "The efficiency of Nitrogen utilization in cereals is generally poor, where it is estimated that only 30–40% of the total of N-fertilizers applied are actually harvested in the grain. The remainder of the applied N is lost to the soil through leaching and runoff, where the often excessive application can affect natural ecosystems through N pollution" (Belete *et al*., 2018). "Many studies have shown genetic variation of wheat in nitrogen uptake so that the use of the best-adapted genotype can contribute to improved efficiency in how cereal crops acquire and use soil N or fertilizer N" (Belete *et al*., 2018).

Application of Nitrogen at 120 kg ha^{-1} for wheat production has been recommended by various researchers to realize the yield potential. Sharifai et *al* (2017) has found higher yield when 120 kg N ha^{-1} was applied irrespective of the variety in northern Nigeria. But when adequate moisture is available, yield responses have been obtained with up to 160 kg ha^{-1} of applied nitrogen fertilizer in southern Alberta. Lacy and Giblin (2006) reported that for a target wheat yield of 8 t/ha and 11.5 % of protein content of the Nitrogen requirement is 210 kg N ha^{-1} while (Faber et al., 2016) found that application of nitrogen at the rates of 144 ± 18 kg N/ha allowed for obtaining the value of Nitrogen Use Efficiency (NUE) of 50 to 90%.

"In Niger Republic wheat is cultivated during the cold off-season under irrigation with an average grain yield of 2.8 ton ha^{-1} (Ministry of Agriculture Niger, 2022). In this country soils are particularly poor in nitrogen and phosphorus leading to low productivity" (Kiari and Ichaou, 2016) and (Henao and Baanante, 2006)). The national consumption of wheat relies mainly on importations, making a heavy import bill. On the other hand, there is a lack of scientific works carried out on wheat crop fertilization; only few researches were made and the results were not documented (Soulé, 2018). The problem of the underuse of nitrogen fertilizer is often reported in developing countries and is associated with a high cost, unavailability, and farmers' limited knowledge about nitrogen fertilizer. (Derara *et al*., 2024). A study made by AcSSA (2010) showed that wheat yield can be increased up to 3-4 tons ha^{-1} in Niger republic through good agronomic practices especially when combining good variety with optimal application of fertilizers. This work was initiated to provide sufficient information on adequate nitrogen fertilization for better grain yield as well as grain protein content, chlorophyll level and nitrogen uptake in grains.

2. MATERIALS AND METHODS

2.1 Study Area

The experiment was conducted during 2016/2017 and 2017/2018 dry and cold seasons at Djirataoua in central south of Niger republic. The experimental field was located in an irrigated orchard lying along the Goulbin Maradi River: 13° 25' 59" North and 7° 8' 12" East, (Google Maps, 2015). Rainfall: 350-600 mm (Sahelian climate). Soil texture: Clay-sand (CEIPI, 2011).

For assessment of the initial soil status, soil samples were collected randomly across the experimental field at a depth from 0–25 cm prior to planting. Physicochemical analysis of the soil samples was performed at Bayero University Soil Department Laboratory, to determine the properties of the soil. The results of soil analysis are presented in Table 1.

2.2 Description of Plant Material

Four (4) wheat varieties were used as plant material and described as follow:

- ''El-Kodaraoua'': local variety widely used by farmers of Djirataoua; Maturity cycle: 85 – 90 days; Plant height: 100 – 115 cm; yield potential: 2 - 3 t ha^{-1}. Grain color: red.
- ''Sokoll/3/'': improved variety, introduced in Niger by University Dan Dicko Dan Koulodo of Maradi (UDDM) from CIMMYT. Maturity cycle: 90 – 95 days; Plant height: 90 – 100 cm; yield potential: 3 - 6 t ha^{-1}. Grain color: white.
- ''Norman": improved variety, introduced in Niger by ICARDA-SARD-SC Wheat Project. Maturity cycle: 95 – 105 days; Plant height: 85 – 100 cm; yield potential: 3 - 6 t ha^{-1}. Grain color: red. This variety has been tested and has performed well in northern Nigeria which is ecologically similar to the area of this study. ''Norman'' is currently being vulgarized in wheat growing areas of Niger republic.
- ''Reyna-28'': improved variety, introduced in Niger by ICARDA-SARD-SC Wheat Project. Maturity cycle: 80 – 90 days; Plant height: 90 – 100 cm; yield potential: 3 - 6 t ha^{-1}.

2.3 Treatments and Experimental Design

The treatments consisted of the combination of four wheat varieties (El-Kodaraoua, Norman, Reyna-28 and Sokoll/3/) and four levels of nitrogen fertilization (0, 100, 150 and 200 kg N ha^{-1}) laid out in Split-plot design with three replications. The main plots were allocated for N fertilizer levels while the wheat varieties were randomly arranged on the sub-plots.

2.4 Plot Size

The unit plot (sub-plot) size for planting was 1.2 m × 2.0 m (2.4 m^2) accommodating 4 rows spaced 30 cm apart. Two central rows with a net plot size of 1.2 m^2 were used for data collection and others measurements. The distance between the main plots and the sub plots was kept 1 m apart.

2.5 Cultural Practices

2.5.1 Land preparation

The experimental site was pre-irrigated, ploughed and harrowed properly. To obtain a fine and flat land the tilth was leveled using rake. The canal was made by hoe with the dimension of 40 cm wideness and 30 cm depth.

2.5.2 Sowing

The sowing was done by means of single row hand drill. Wheat seeds were drilled in the rows with 30 cm inter-row spacing on sub-plots. The sowing was done on 25 November 2016 during 2016/2017 dry season and 13 November 2017 during 2017/2018 dry season.

The seeds were treated with the chemical ''Calthio'' at the rate of 10 g kg^{-1} of seed before sowing

2.5.3 Fertilization

Fertilizers were applied in the form of NPK (15-15-15), SSP (0-18-0) and Urea (46-0-0). The Phosphorus and Potassium fertilizers were applied at the constant rate of 60 kg/ha and 40 kg/ha respectively as recommended, while the N fertilizer was applied at various levels according to the treatment. The NPK and the SSP fertilizers were applied at the time of sowing and the Urea was top-dressed and applied in single application at the stage of first node emergence (jointing stage).

2.6 Data Collection

2.6.1 Chlorophyll content

The chlorophyll content was measured before the heading stage using a chlorophyll meter device (SPAD 502) on the young leaves of the ten labeled plants and the mean value was recorded for the corresponding plot.

2.6.2 Nitrogen uptake (in grains)

Grain samples were collected and analyzed for N content in laboratory.

Total uptake of N was calculated separately by the following formula (Sharma *et al*., 2012):

$$N\ Uptake\ (kg\ ha^{-1}) = \frac{N\% \times GY(kg\ ha^{-1})}{100}$$

Where:
N% = Nitrogen content in grain (%).
GY = Grain yield (kg ha^{-1})

2.6.3 Protein Content (in grains)

The protein content (PC) of grains was calculated from the N content in whole wheat grain using a conversion factor (5.83) as described by Merrill and Watt (1973) with the following formula:

$$PC\ (g\ kg^{-1}) = N(g\ kg^{-1}) \times 5.83$$

Where:
N (g kg^{-1}) = Nitrogen content in grain (g kg^{-1}).
5.83 = conversion factor for wheat crop.

2.6.4 Grain Yield

For each unit plot the central rows were harvested. After threshing, the grains were weighed and the value was used for grain yield calculation.

2.7 Data Analysis

Data were subjected to the analysis of variance (ANOVA) to sort out significant difference among treatments using the software GENSTAT 18th Edition and mean comparison was performed using Fisher protected LSD at 5% level of significance.

3. RESULTS

3.1 Chlorophyll Content (in leaves)

The Nitrogen fertilization had significantly affected the chlorophyll content of wheat in both seasons (Table 2). In 2016/2017 the highest value of chlorophyll was observed at 200 kg N ha^{-1} (51.12 SPAD units), 150 kg N ha^{-1} (51.75 SPAD units) and100 kg N ha^{-1} (50.73 SPAD units). The lowest chlorophyll (35.0 SPAD units) content was recorded at 0 kg N ha^{-1}. The similar trend of results was observed in 2017/2018 where chlorophyll content was similarly highest at 100, 150 and 200 kg N ha^{-1}. This result showed an increase in chlorophyll content with increase of N level up to 100 kg N ha^{-1} beyond which no significant increase in chlorophyll was observed.

Significant difference in chlorophyll content was observed among wheat varieties during both dry seasons. In 2016/2017 the results revealed two groups of varieties: Norman and Sokoll/3/ produced the highest level of chlorophyll with respectively 49.64 and 49.58 SPAD-units while the lowest chlorophyll content was observed on Reyna-28 (44.76 SPAD-units) and El-Kodaraoua (44.62 SPAD-units). In 2017/2018 dry season Norman produced the highest level chlorophyll (52.62 SPAD-units) followed by Sokoll/3/ (50.39 SPAD-units). The local variety El-Kodaraoua produced the lowest content of chlorophyll (41.03 SPAD-units).

The interaction Nitrogen x variety on chlorophyll content was highly significant (P< .001) during both seasons (Table 3). The result of mean comparison showed the highest level of chlorophyll at interaction 150 kg N ha^{-1} x Sokoll/3/ with 53.86 SPAD-units. The lowest chlorophyll content was recorded at interaction 0 kg N ha^{-1} x El-Kodaraoua (29.08 SPAD-units). The similar tendancy was observed in 2017/2018.

3.2 Nitrogen Uptake (in grains)

In 2016/2017 the effect of Nitrogen fertilization on Nitrogen uptake (NU) of wheat grains was highly significant (Table 2). Plants fertilized at 150 kg N ha^{-1} had up-taken more Nitrogen (74.38 kg ha^{-1}) in grains followed by treatments at 100 and 200 kg N ha^{-1} which recorded a similar NU, while the lowest NU (11.08 kg ha^{-1}) was observed at the control treatment. Highly Significant difference (P< .001) in NU of wheat grains was observed among wheat varieties at Djirataoua. Reyna-28 and Sokoll/3/ recorded the highest NU with 58.52 and 54.62 kg ha^{-1} respectively, followed by Norman (49.10 kg ha^{-1}) while the lowest NU (39.43 kg ha^{-1}) was observed in the local variety El-Kodaraoua. In 2017/2018 dry season the Nitrogen fertilization had significantly (P< .001) influenced the NU of wheat where the results of grains analysis showed the highest NU at 100 and 150 kg N ha^{-1} with 61.7 and 70.88 kg ha^{-1} respectively. The NU at 200 kg N ha^{-1} was statistically similar to that of 100 kg N ha^{-1} while the lowest NU (20.89 kg ha^{-1}) was found at the control treatment. There was a significant influence of wheat varieties on NU of wheat; Sokoll/3/ had up-taken more nitrogen with 66.49 kg ha^{-1}, followed by Reyna-28 (58.3 kg ha^{-1}) while the local variety El-Kodaraoua recorded the lowest NU (38.6 kg ha^{-1}).

Interaction between Nitrogen fertilization and variety on NU was highly significant (Table 4). Considering the varieties individually it was observed for Sokoll/3/ and Reyna-28 an increase in NU from the lowest value at 0 kg N ha^{-1} to the highest NU at 150 kg N ha^{-1} while El-Kodaraoua and Norman reached the highest NU at 100 kg N ha^{-1}. The mean comparison showed the highest NU at two interactions: 150 kg N ha^{-1} x Reyna-28 (88.38 kg ha^{-1}) and 150 kg N ha^{-1} x Sokoll/3/ (82.85 kg ha^{-1}) while the lowest NU in grains was observed at interactions between 0 kg N ha^{-1} with all wheat varieties.

3.3 Protein Content

In 2016/2017 dry season the Nitrogen fertilization had significantly influenced the protein content of wheat grains (Table 2). Application of Nitrogen at 150 kg N ha^{-1} resulted in highest protein content in grains (135 g kg^{-1}), followed by treatment at 100 kg N ha^{-1} (118.6 g kg^{-1}) while the lowest level of protein (105.3 g kg^{-1}) was recorded at 0 kg N ha^{-1}. The four wheat varieties were significantly different (P< .001) in protein content during 2016/2017 dry season. The local variety El-Kodaraoua and Norman were statistically similar and produced highest protein content with 120.9 and 120.5 g kg^{-1} respectively followed by Sokoll/3/ (117.2 g kg^{-1}) while the lowest protein content (112.8 g kg^{-1}) was observed in grains of Reyna-28. In 2017/2018 application of Nitrogen at 100 and 150 kg N ha^{-1} were statistically similar and produced the highest protein content in grains with 132.6 and 136 g kg^{-1} respectively, followed by the treatment at 200 kg N ha^{-1} (125.6 g kg^{-1}) while the lowest level of protein (109 g kg^{-1}) was observed at 0 kg N ha^{-1}. There was a statistically significant (P< .001) difference in protein content among the four wheat varieties during 2017/2018 dry season. Sokoll/3/ produced the highest protein content (139.9 g kg^{-1}) while the three other varieties were statistically similar in protein content as follow: El-Kodaraoua (122.3 g kg^{-1}), Norman (119.7 g kg^{-1}) and Reyna-28 (121.3 g kg^{-1}). The interaction between Nitrogen fertilization and wheat variety on protein content was statistically significant (Table 5). Considering the varieties individually it was observed for El-Kodaraoua and Reyna-28 an increase in protein content from the lowest value at 0 kg N ha^{-1} to the highest protein content at 150 kg N ha^{-1} beyond which there was a decrease. Whereas Sokoll/3/ achieved the highest protein content at 100 kg N ha^{-1} and then a decrease. The variety Norman showed an inconsistent decrease in protein content from the highest value at 0 kg N ha^{-1} to the lowest level at the rest of N treatments. The results of mean comparison indicated the highest protein content at interactions 150 kg N ha^{-1} x Reyna-28 (151.3 g kg^{-1}) and 150 kg N ha^{-1} x El-Kodaraoua (150.6 g kg^{-1}) while the lowest protein content was observed at interaction 0 kg N ha^{-1} x Reyna-28 (90.7 g kg^{-1}).

Table 1. Physical and chemical properties of experimental soil (0-25 cm)

Physical properties	
Particle size distribution (g kg^{-1})	
Sand	510.60
Silt	327.70
Clay	161.60
Texture	Loamy
Water Holding Capacity (%)	57.2
Chemical properties	
pH (H_2O)	6.62
pH ($CaCl_2$)	6.06
Organic Matter (g kg^{-1})	9.94
Nitrogen $NH4^-$ (g kg^{-1})	0.05
Nitrogen $NO3^-$ (g kg^{-1})	0.02
Total Nitrogen (g kg^{-1})	1.05
Available Phosphorus (mg kg^{-1})	5.94
Exchangeable Cations (Cmol kg^{-1})	
K	0.26
Na	0.38
Ca	1.15
Mg	1.18
CEC	3.30

Source: Soil Lab, Department of Soil Science, Bayero University, Kano

Table 2. Mean value for the effects of Nitrogen rates (N), variety (V) and interactions (N x V) on grain yield (GY), chlorophyll content (CC), Nitrogen uptake (NU) and protein content (PC) during 2016/2017 and 2017/2018

	2016/2017				**2017/2018**			
	CC	**NU**	**PC**	**GY**	**CC**	**NU**	**PC**	**GY**
Nitrogen(N)								
0	35.00b	11.08c	105.30d	596c	38.42b	20.89c	109.00c	1461c
100	50.73a	57.73b	118.60b	278 b	48.77a	61.70ab	132.60a	2354b
150	51.75a	74.38a	135.00a	3202a	50.05a	70.88a	136.00a	2500ab
200	51.12a	58.48b	112.50c	3106ab	50.68a	60.88b	125.60b	2719a
LSD (5%)	1.321	12.372	1.362	326	1.982	9.902	6.946	348
Variety: V								
Local variety	44.62b	39.43c	120.90a	1825c	41.03d	38.60d	122.30b	1846c
Sokoll/3/	49.58a	54.62ab	117.20b	2701a	50.39b	66.49a	139.90a	2584b
Norman	49.64a	49.10b	120.50a	2322b	52.62a	50.97c	119.70b	1690c
Reyna 28	44.76b	58.52a	112.80c	2842a	43.88c	58.30b	121.30b	2914a
LSD (5%)	1.149	5.805	1.353	231.1	1.022	6.94	6.034	237.6
Interactions								
N x V	< .001**	< .001**	< .001**	0.004**	< .001**	< .001**	< .001**	0.004**

Means in the same column followed by the same letter (s) are not significantly different at 5% level of probability using Fisher's Least Significant Difference

Table 3. Interaction of Nitrogen fertilization and variety (N x V) on chlorophyll content (SPAD value) of wheat in 2016/2017 and 2017/2018

Treatments	Variety			
	El Kodaraoua	**Sokoll/3/**	**Norman**	**Reyna-28**
Nitrogen (kg ha^{-1})		**2016-2017**		
0	29.08f	38.67d	40.19d	32.08e
100	48.88c	53.00a	52.71ab	48.33c
150	50.57bc	53.86a	53.14a	49.44c
200	49.98 c	52.8ab	52.52ab	49.17c
LSD (0.05)		2.345		
Nitrogen (kg ha^{-1})		**2017-2018**		
0	29.82i	43.79fg	45.78def	34.30h
100	43.08g	52.26c	53.57bc	46.19def
150	45.70def	52.48bc	54.60ab	47.43de
200	45.51efg	53.06bc	56.53a	47.61d
LSD (0.05)	2.598			

Means followed by the same letter (s) are not significantly different at 5% level of probability using Fisher's Least significant difference

Table 4. Interaction of Nitrogen fertilization and variety (N x V) on Nitrogen Uptake (kg ha $^{-1}$) of wheat during 2016/2017 and 2017/2018 dry seasons

Treatments	Variety			
	El-Kodaraoua	Sokoll/3/	Norman	Reyna-28
Nitrogen (kg ha^{-1})		**2016/2017**		
0	6.86g	11.56g	12.77g	13.12g
100	50.00ef	73.02bc	53.46de	54.43de
150	63.15cde	82.85ab	63.14cde	88.38a
200	37.73f	51.03e	67.02cd	78.14abc
LSD (0.05)	15.186			
Nitrogen (kg ha^{-1})		**2017/2018**		
0	15.37hi	27.45gh	12.09i	28.66gh
100	53.13de	63.79bcd	52.70de	77.19b
150	37.58fg	100.42a	76.26b	69.24bc
200	48.34ef	74.28b	62.81bcd	58.1cde
LSD (0.05)	14.899			

Means followed by the same letter (s) are not significantly different at 5% level of probability using Fisher's Least significant difference

Table 5. Interaction of Nitrogen Fertilization and Variety (N x V) on Protein Content (g kg^{-1}) of Wheat during 2016/2017 and 2017/2018 dry seasons

Treatments	Variety			
	El-Kodaraoua	Sokoll/3/	Norman	Reyna-28
Nitrogen (kg ha^{-1})		**2016/2017**		
0	94.90i	104.50h	131.10c	90.70jk
100	125.50d	140.90b	119.20e	89.10k
150	150.60a	130.60c	107.50g	151.30a
200	112.60f	93.00ij	124.30d	120.20e
LSD (0.05)	2.624			
Nitrogen (kg ha^{-1})		**2017/2018**		
0	102.40ij	134.30cde	94.40j	104.90hij
100	143.00bc	130.40de	115.40fgh	141.80bcd
150	111.90ghi	155.30a	151.60ab	125.20ef
200	131.80cde	139.80bcd	117.50fg	113.30fghi
LSD (0.05)	12.089			

Means followed by the same letter (s) are not significantly different at 5% level of probability using Fisher's Least significant difference

Table 6. Interaction of nitrogen fertilization and variety on grain yield (kg ha^{-1}) of Wheat in 2016/2017 and 2017/2018

Treatments	Variety			
	El-Kodaraoua	Sokoll/3/	Norman	Reyna-28
Nitrogen (kg ha^{-1})	**2016-2017**			
0	404g	637g	551g	793g
100	2238f	3094cd	2468ef	3342bcd
150	2465ef	3652ab	3327bcd	3364a-d
200	2192f	3422abc	2944de	3867a
LSD (0.05)	505.5			
Nitrogen (kg ha^{-1})	**2017-2018**			
0	1171hi	1406hi	988i	2281def
100	2002fg	2750cd	1593gh	3073abc
150	2246df	2843bc	2174f	2736cde
200	1965fg	3338ab	2006fg	3566a
LSD (0.05)	527.5			

Means followed by the same letter (s) are not significantly different at 5% level of probability using Fisher's Least significant difference

3.4 Grain Yield

The effect of Nitrogen fertilization was highly significant (P< .001) during both seasons (Table 2). In 2016/2017 the highest GY was produced with application of 150 kg N ha^{-1} (3202 kg ha^{-1}) and 200 (3106 kg ha^{-1}) while the lowest GY (596 kg ha^{-1}) was produced at the control treatment (0 kg N ha^{-1}). In 2017/2018 dry season application of Nitrogen at 150 and 200 kg N ha^{-1} were statistically similar and produced the highest GY with respectively 2500 and 2719 kg ha^{-1}. The lowest GY (1461 kg ha^{-1}) was recorded at 0 kg N ha^{-1}. For both dry seasons the same tendency was observed showing the increase in GY with increasing levels of Nitrogen up to 150 kg N ha^{-1} beyond which there was no significant increase in GY. The effect of wheat varieties on GY was highly significant (P< .001) during both dry seasons. In 2016/2017 the results showed the best performance of Reyna-28 and Sokoll/3/ in GY production with 2842 and 2701 kg ha^{-1} respectively followed by Norman (2322 kg ha^{-1}). The lowest GY was produced by the local variety El-Kodaraoua (1825 kg ha^{-1}). In 2017/2018 dry season the variety Reyna-28 topped in GY with 2914 kg ha^{-1} followed by Sokoll/3/ (2584 kg ha^{-1}). Norman and El-Kodaraoua produced lowest GY with 1690 and 1846 kg ha^{-1} respectively. A similar tendency of results was observed during both seasons showing the superiority of variety Reyna-28 in grain yield formation (2878 kg ha^{-1}) while the local variety El-Kodaraoua produced the lowest GY (1835 kg ha^{-1}). The interaction of Nitrogen fertilization and variety on GY was statistically significant (P≤0.05) for both seasons (Table 6). The mean comparison showed that in 2016/2017 the highest GY was obtained with interaction 200 kg N ha^{-1} x Reyna-28 (3867 kg ha^{-1}), whereas the least interactive effect on GY was observed at interaction 0 kg N ha^{-1} x El-Kodaraoua (404 kg ha^{-1}). In 2017/2018 dry season the results showed the best response of the varieties Reyna-28 and Sokoll/3/ to 200 kg N ha^{-1} with respectively 3566 kg ha^{-1} and 3338 kg ha^{-1}.

The evolution of the three parameters (CC, NU and PC) to nitrogen rates is shown on Fig. 1. It was globally observed a constant increase of chlorophyll content from 0 to 200 kg N ha^{-1}. The Nitrogen uptake and protein content increased from 0 to 150 kg N ha^{-1} and decreased.

4. DISCUSSION

The effect of Nitrogen on chlorophyll content in plant leaves was probably due to the mobilization and utilization of available Nitrogen by wheat plant to produce higher chlorophyll content because Nitrogen is a major component of chlorophyll. This is in agreement with Bojovič and Stojanovič (2005) who reported that, greatest chlorophyll content in wheat plants was measured on the soil fertilized with Nitrogen level of 150 kg ha^{-1}; furthermore Ilze and Ruza (2017) obtained the maximum value of chlorophyll content at 175 kg N ha^{-1}. In this study the highest Nitrogen uptake (NU) at 150 kg N ha^{-1} during both growing seasons which could be explained by the extraction and translocation of Nitrogen in grains when N fertilizer is optimally applied. The similar trend was found by Wang et al. (2010) who observed an increase in N uptake of wheat

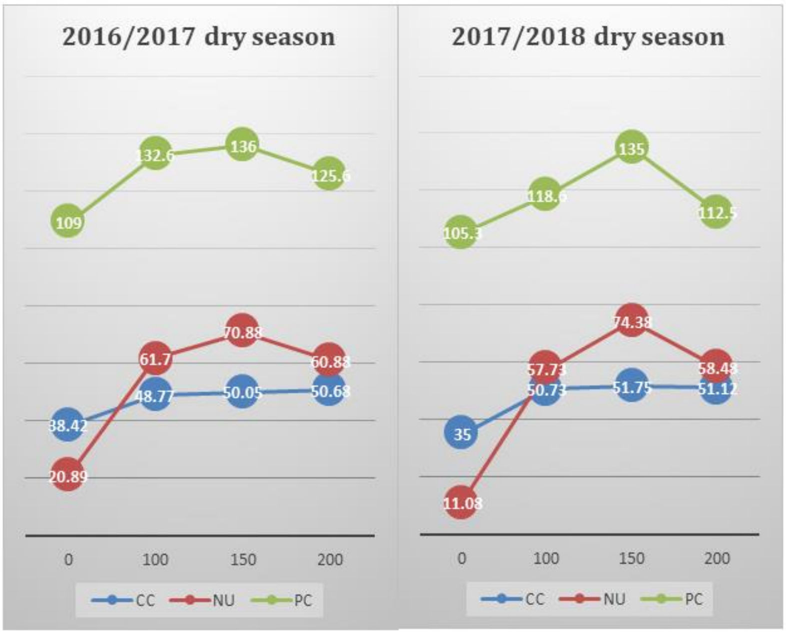

Fig. 1. Variation of CC (SPAD unit), NU (kg ha^{-1}) and PC (g kg^{-1}) at different N levels

from 0 kg N ha^{-1} to 221 kg N ha^{-1} and afterwards declined at 300 kg N ha^{-1}. The protein content (PC), the most important indicator of wheat grain quality (Litke et al., 2018), was significantly influenced by Nitrogen application during both dry seasons. The highest PC was achieved by application of 150 kg N ha^{-1} of Nitrogen. This result follows the same trend with the findings of Yunqi *et al*. (2023) and Weber et al. (2008) demonstrating that protein content of wheat grain was significantly influenced by Nitrogen treatment and that the protein content in wheat grain increased in correlation with the nitrogen rate increase. According to Litke et al. (2018), the standards for food quality of wheat grain suggested protein content from a minimum of 12% (120 g kg^{-1}). In this study, the highest protein content, which conforms to food quality standards, was obtained using Nitrogen fertilizer rate of 150 kg N ha^{-1} (135 g kg^{-1}). However, Weber et al. (2008) found that N-rate of 180 kg N ha^{-1} was needed to obtain protein content suitable for bread baking.

The high variation in grain yield, Nitrogen uptake, protein content and chlorophyll content was found among wheat varieties showing a differential genetic make-up of this germplasm as reported by Diekmann and Fishbeck (2005) who stated that, genotypic differences in grain yield formation of wheat are linked to a variety of morphological and physiological factors that affect uptake and utilization of Nitrogen. Also, Woyema et al. (2012) observed an increase in grain N uptake by wheat depending on the cultivars potentials to absorb N more efficiently from the soil.

The significant interaction between Nitrogen and variety on grain yield, chlorophyll content, Nitrogen uptake and protein content might indicate that for good response of these characters to Nitrogen fertilizer the variety choice was very necessary. This is in concordance with Woyema et al. (2012) who reported that, the choice of genotype and optimum Nitrogen fertilization is one of the recognized cultivation techniques that have large influence on growth, grain yield and quality in wheat grain production.

The highest grain yield was achieved at 150 kg N ha^{-1} during both growing seasons. This might be due to the well-balanced supply of Nitrogen having resulted in higher net assimilation rate and increased grain yield as reported by Sage and Pearcy (1987). In this line, Arnon (1972) explained that high Nitrogen supply favors the conversion of carbohydrates into proteins, which in turn promotes the formation of protoplasm. The range of our result is in conformity with the findings of Heinemann et al. (2006) who reported that, for irrigated wheat, it was observed a positive and highest response of grain yield up to 156 kg ha^{-1} of Nitrogen.

5. CONCLUSION

The findings of this study revealed that grain yield, chlorophyll content, nitrogen uptake and protein content of wheat varieties varied significantly in response to Nitrogen fertilization in the study area. The grain yield and the other studied characters increased with higher Nitrogen level up to 150 kg N ha^{-1} beyond which there was no significant increase. The varieties Reyna-28 and Sokoll/3/ produced higher grain yield, Nitrogen uptake and protein content. The chlorophyll content was highest with variety Sokoll/3/. The best interactions of Nitrogen rates and varieties were 150 kg N ha^{-1} x Sokoll/3/ and 150 kg N ha^{-1} x Reyna-28 on all studied characters. Therefore it can be recommended to wheat farmers of this region to grow the variety Sokoll/3/ or Reyna-28 with application of 150 kg N ha^{-1} for high grain yield and protein content.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

AcSSA-Afrique verte. (2010). Actions pour la sécurité et la souveraineté alimentaires au Niger dans études sur les possibilités d'améliorer les cultures de maïs et de blé à Agadez au Niger. *Rapport Final de l'Etude*. French.

Arnon, I. (1972). Plant population and distribution patterns in crop production in dry regions. *National Book Foundation Islamabad, Pakistan*, 1, 443-456.

Asmund, B. (2016). Wheat - Its role in social and cultural life: Attributes of winter wheat in the Great Plains. *Crop Science, 41*, 1412-1419.

Belete, F., Nigussie, D., Adamu, M., & Tamado, T. (2018). Effect of nitrogen fertilizer rates on grain yield and nitrogen uptake and use efficiency of bread wheat (*Triticum aestivum*) varieties on the Vertisols of central highlands of Ethiopia. *Agriculture & Food Security, 7*, 78.

Bojovič, B., & Stojanovič, J. (2005). Chlorophyll and carotenoid content in wheat cultivars as a function of mineral nutrition. *Archives of Biological Sciences, 57*(4), 283–290.

CEIPI. (2011). Centre d'Etude et d'Information sur la Petite Irrigation Projets et Programmes de Développement de l'Irrigation au Niger. French.

Cutts, M., & Pauly, D. (2001). Wheat nutrition and fertilizer requirements: Nitrogen. *Agriculture News for Agriculture and Forestry*, 1-20.

Derara, S. F., Xiaoqiang, J., & Dagne, M. (2024). Wheat yield response to chemical nitrogen fertilizer application in Africa and China: A meta-analysis. *Journal of Soil Science and Plant Nutrition, 24*, 102–114. https://doi.org/10.1007/s42729-023-01609-5

Diekmann, F., & Fischbeck, G. (2005). Differences in wheat cultivar response to nitrogen supply: Differences in grain yield formation. *Journal of Agronomy and Crop Science, 191*, 351 - 361.

Faber, A., Jaros, Z., & Jadczyszyn, T. (2016). Nitrogen use efficiency of winter wheat on farms in Poland. *Polish Journal of Agronomy*, 26-33.

FAO. (2022). *The State of Food Security and Nutrition in the World 2022: Safeguarding against economic slowdowns and downturns*. Rome.https://policycommons.net/artifacts/2483950/the-state-of-food-security-and-nutrition-in-the-world-2022/3506270/

Fixen, P., Frank, B., Bruulsema, T., Fernando, G., Norton, R., & Zingore, S. (2014). Nutrient and fertilizer use efficiency: Measurement, current situation and trends. *IFA, IWMI, IPNI and IPI*, 1-30.

Heinemann, A. B., Stone, L. F., Didonet, A. D., Trindade, M. G., Soares, B. B., Moreira, A. A., & Canovas, A. D. (2006). Efficiency of use of solar radiation and nitrogen fertilization on the productivity of wheat. *Brazilian Journal of Agriculture, 10*(2), 352-356.

Henao, J., & Baanante, C. (2006). *Agricultural production and soil nutrient mining in Africa: Implication for resource conservation and policy development*. IFDC Tech. Bull. International Fertilizer Development Center, Muscle Shoals, AL, USA.

Ilze, S., & Ruza, A. (2017). Effect of nitrogen and sulphur fertilization on chlorophyll content in winter wheat. *Rural Sustainability Research, 37*(332). ISSN – 2256-0939.

Kiari, A. S., & Ichaou, A. (2016). Gestion durable des sols au Niger: Contraintes, défis, opportunités et priorités. *Nature et Faune, French. 30*(1), 31-34.

Lacy, J., & Giblin, K. (2006). Growing eight tons a hectare of irrigated wheat in southern NSW. *Prime Fact, 197*.

Litke, L., Gaile, Z., & Ruza, A. (2018). Effect of nitrogen fertilization on winter wheat yield and yield quality. *Agronomy Research, 16*(2), 500-509.

Ma, B. L., Wu, T. Y., Tremblay, N., Deen, W., McLaughlin, N. B., Morrison, M. J., & Stewart, G. (2010). On-farm assessment of the amount and timing of nitrogen fertilizer on ammonia volatilization. *Agronomy Journal, 102*(1), 134-144.

Merrill, A. L., & Watt, B. K. (1973). *Energy Value of Foods: Basis and Derivation*. Agriculture Handbook No. 75, United States Department of Agriculture, Washington DC.

Ministry of Agriculture Niger. (2022). Direction des statistiques agricoles. Rapport de production des cultures irriguées. French.

Raun, W. R., & Johnson, G. V. (1999). Improving nitrogen use efficiency for cereal production. *Agronomy Journal, 91*(3), 357-363.

Reynolds, M. P., & Braun, H. J. (2023). Wheat Improvement. International Maize and Wheat Improvement Centre (CIMMYT), Texcoco, Mexico. (Eds.). https://doi.org/10.1007/978-3-030-90673-3_1

Riley, W. J., Ortiz-Monasterio, I., & Matson, P. A. (2001). Nitrogen leaching and soil nitrate, nitrite, and ammonium levels under irrigated wheat in northern Mexico. *Nutrient Cycling in Agroecosystems, 61*(3), 223-236.

Sage, R. F., & Pearcy, R. W. (1987). The nitrogen use efficiency of C3 and C4 plants. *Plant Physiology, 84*, 954-958.

Sharifai, A. I., Abubakar, I. U., Hussaini, Y., & Kura, H. N. (2017). Performance of wheat varieties as affected by nitrogen rate in Sudan agro-ecological zone of Nigeria. *International Wheat Conference*, 27th Feb. – 2nd March 2017, Abuja, Nigeria.

Sharma, N. K., Raman, J. S., & Kumar, K. (2012). Dry matter accumulation and nutrient uptake by wheat (*Triticum aestivum*) under poplar (*Populus deltoides*) based agroforestry system. *International Scholarly Research Network ISRN Agronomy*, 1-7.

Soulé, A. M. (2018). *Response of wheat varieties to irrigation interval and nitrogen fertilization in southern agro-ecological zone of Niger republic* (PhD thesis). Bayero University of Kano, Nigeria.

Wang, Q., Fengrui, L., Lin, Z., Zhang, E., Shangli, S., Zhao, S., Weixin, S., & Maureen, M. V. (2010). Effects of irrigation and nitrogen application rates on nitrate nitrogen distribution and fertilizer nitrogen loss, wheat yield and nitrogen uptake on a recently reclaimed sandy farmland. *Plant Soil, 337*, 325–339.

Weber, E. A., Graeff, S., Koller, W. D., Hermann, W., Merkt, N., & Claupein, W. (2008). Impact of nitrogen amount and timing on the potential of acrylamide formation in winter wheat (*Triticum aestivum* L.). *Field Crops Research, 106*, 44-52.

Woyema, A., Bultosa, G., & Taa, A. (2012). Effect of different nitrogen fertilizer rates on yield and yield related traits for seven durum wheat (*Triticum turgidum* L.) cultivars grown at Sinana, South Eastern Ethiopia. *African Journal of Food, Agriculture, Nutrition and Development, 12*(3).

Yunqi, W., Yu, P., Jiaqi, L., Lixin, W., Zhikuan, J., & Rui, Z. (2023). Optimal nitrogen management to achieve high wheat grain, grain protein content, and water productivity: A meta-analysis. *Agricultural Water Management, 290*, 108587.

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