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Optimization of Nitrogen and Phosphorus Rates for Grain Yield and Quality of Durum Wheat (*Triticum turgidum L. var Durum*) in Koga and Rib Irrigation Schemes, Northwestern Ethiopia

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ABSTRACT

Durum wheat is one of the most important food and cash crops in Ethiopia. However, the productivity of the crop is low due to a lack of appropriate agronomic recommendations. Therefore, a field experiment was conducted from 2019-2020 G.C. to determine nitrogen and phosphorus rates in Koga and Rib irrigation schemes. The treatments consisted of factorial combinations of four levels of nitrogen (0, 92, 184, and 276 kg ha^{-1}) and three levels of P_2O_5 (0, 46, and 92 kg ha^{-1}) in a randomized complete block design with three replications. Agronomic data, including plant height, number of effective tillers, spike length, grain per spike, thousand kernels weight, biomass yield, grain yield, and protein content, were collected and analyzed through SAS system. Partial budget analysis was performed to ensure the economic feasibility of treatment combinations. The results showed that the highest grain yield (ETB 4841 kg ha^{-1}) was recorded at 184 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1} at Koga irrigation scheme, whereas in Rib, the highest grain yield (5354 kg ha^{-1}) was recorded at 276 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1}. The protein content and other quality parameters were high enough to meet the quality standards at the maximum rate of nutrient combinations. An economic optimum marginal rate of return was also obtained from 184 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1} rates at Koga irrigation scheme and at 276 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1} at Rib irrigation scheme. Hence, combined application of 184 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1} at Koga and 276 kg N ha^{-1}and 92 kg P_2O_5 ha^{-1} rates in Rib irrigation scheme are recommended for optimum quality and economically feasible grain yield production.

1. INTRODUCTION

Durum wheat (*Triticum turgidum* L. var. Durum) is one of the most widely grown crops in Ethiopia. The crop has been cultivated for thousands of years and is considered the second most cultivated wheat species next to bread wheat (Tidiane *et al.*,2019). Area coverage for Wheat production and productivity in Ethiopia remained at 1,789,372.23 hectares and 2.97 t ha^{-1}, respectively in Ethiopia (USDA, 2021). Reliable information on the production and productivity of durum wheat alone is limited because production statistics for durum and bread wheat are often confounded together. However, according to Teklu & Hammer (2008) durum wheat accounts for more than 20% of the total wheat production and is estimated to contribute between 18 and 20% of the national wheat grain yield in Ethiopia.

The average productivity of wheat (2.97 t ha^{-1}) in Ethiopia is by far lower than the average world productivity of 3.51 t ha^{-1} (USDA, 2021). This is owing to continuous nutrient uptake, low fertilizer use, insufficient organic matter application, and other inappropriate agronomic practices (Tamene *et al.*, 2017). This condition is particularly prevalent in Ethiopia's intensively cultivated areas, where irrigation systems are common. Soil nutrient deficiency is the most significant factor controlling crop yield in the country at large (Hawando, 1989). In other similar studies (EthioSIS, 2014), reported that the problem of soil nutrient deficiency is critical in Ethiopia. Concurrently, Mamo *et al. (*1988) reported that the nutrient status of Ethiopian soils is low and is the primary limiting factor for crop production.

Synthetic fertilizers, i.e., fertilizers containing nitrogen and phosphorus, unquestionably increase crop productivity and soil fertility. Nitrogen and phosphorus in the form of urea and Diammonium phosphate are the major fertilizers applied by Ethiopian smallholder farmers. The effect of nitrogen and phosphorus nutrients in increasing the yield of durum wheat is quite high, and the greatest yield is obtained from both nutrients. Nitrogen influences the crop's protein content, seed size, and plant growth. Phosphorus has a vital role in crop maturity, flowering, fruiting, including seed formation, albumen formation, and cell division (Brady & Weil, 2002). Depending on local soil conditions, an economic optimum nitrogen and phosphorus application gave 5 to 6 t ha^{-1} of grain yield of durum wheat in Ethiopia, Gezahegn e*t al.* (2022). According to Abebe & Manchore (2016), nitrogen and phosphorus applied at 69 kg N and 46 kg (P_2O_5) ha^{-1} showed more tillers, thousand seed weight, biomass, straw, and grain yields than the unfertilized control. Similarly, Ishete & Tana (2019) showed that applications of 92 kg ha^{-1} N and 92 kg (P_2O_5) ha^{-1} showed the maximum grain yield (5738 kg ha^{-1}) of durum wheat in Balie areas.

Currently, durum wheat grain yield and quality-enhancing technology is getting due attention because of the growing number of industrial parks that use durum wheat as a raw material in the country in general and in the region in particular (Eshetie, 2018). Approximately 250,000 tons of grain are required by the factory annually to produce pasta to full capacity. However, due to the shortage of durum wheat grains in the country, pasta and macaroni-processing factories imported durum wheat grains from abroad to satisfy their annual grain demand. However, due to a shortage of foreign currency, there is a strong interest in producing the grain locally. Irrigable durum wheat production is an untapped area obtaining serious attention from the government. However, substitution of such volume grain is impossible without the integration of efforts in all dimensions. The role of improved variety and appropriate fertilizer recommendation is quite tremendous to achieve the goal of import substitution. Despite research to determine optimum nitrogen and phosphorus rates not having been carried out so far at Koga and Rib irrigation schemes. Therefore, the study was conducted to determine the economic optimum nitrogen and phosphorus rates to boost durum wheat production and satisfy the needs of the emerging factories.

2. MATERIALS AND METHODS

2.1. Description of the Study Area

The experiment was conducted in between November and March at Koga and Rib irrigation scheme from 2019 to 2020 G.C. Koga and Rib irrigation sites are the largest schemes with irrigable land of 7,000 and 11,000 hectares; respectively, in northwestern Ethiopia. Temperature ranged from 9.7 to 27 ^{o}C and 11 to 30 ^{o}C for Koga and Rib, respectively. Koga is located at altitudinal range of 1840-1921 meter above sea level (Figure 1). The geographical location lies between 11^{o} 25'20'' N latitude and 37^{o} 10'20" E longitude. The soil type is Nitosols, which is slightly to strongly acidic, high exchangeable acidity and exchangeable Al^{3+} content (Agumas *et al* 2014). Maize (*Zea mays*), wheat (*Triticum aestivum*), cabbage (*Brassica oleracea*) and potato (*Solanum tubersosum*), onion (*Allium cepa*), pepper (*Capsicum annum*) and tomato (*Lycopersicon esculentum*) are the most producing crop at Koga irrigation scheme.

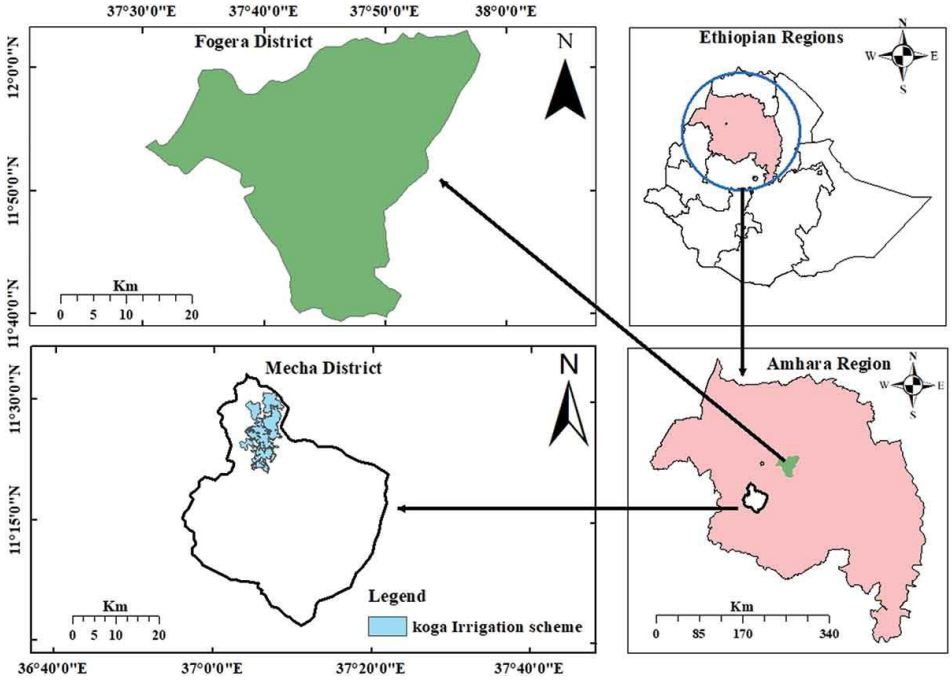


Figure 1: Map of the study area (Source: Enyew *et al* 2020)

Rib is located in Amhara regional state, south Gonder administrative zone of Fogera district. The site is geographically located at 11° 41' to 12° 02' N latitude and 37° 29' to 37°59' E longitude. The elevation ranges between 1800 and 185 above sea level. The soil type is Fulivisols with relatively moderate soil nutrient status. Crops such as, maize (*Zea mays*), wheat (*Triticum aestivum*), cabbage (*Brassica oleracea*), potato (*Solanum tubersosum*), onion (*Allium cepa*) and pepper (*Capsicum annum*) and tomato (*Lycopersicon esculentum*) are producing in Rib irrigation scheme. The yearly average minimum and maximum temperature is 8 and 30.4 ^{o}C, respectively (Agumas *et al.*, 2014).

2.2. Experimental Setup

The experiment consisted of a factorial combination of four levels of nitrogen (0, 92, 184, and 276 kg ha^{-1}) and a three-level of phosphorus, P_2O_5 (0, 46, and 92 kg ha^{-1}) in a randomized complete block design with three replications. The gross size of the experimental plots was 2 m x 3.2 m (6.4 m^2), and 50 cm wide paths separated adjacent plots. For every four rows of wheat, a 40 cm furrow width was used to irrigate the plots. Each plot had 12 rows. Blocks were separated by 1 meter from each other. The field plowed four times using oxen-drawn plow. The seed was drilled at a seeding rate of 150 kg ha^{-1} and rows spacing was 20 cm. Urea and DAP fertilizers were used as a source of nitrogen and phosphorus nutrients. All P and one-third of the N were applied at sowing time. The remaining two-thirds of N containing nutrients were applied at the tillering stage. Cultural operations like weeding

and pest control were applied uniformly to all plots. Weeds were periodically removed by hand, while diseases (leaf rust) and insects (aphids) were controlled by fungicides (tilt 0.5 kg ha^{-1}) and insecticides (Cypermethrin 1-liter ha^{-1}).

2.3. Data Collection, Measurement and Analysis

Agronomic data including plant height, number of effective tillers, spike length, grain per spike, thousand kernels weight, biomass, and grain yield were collected from a net plot of 1.6*2.8 meters. Plant height was recorded from five randomly selected plants by measuring from the ground to the top of the spike, excluding the awns. Numbers of effective tillers per row length were measured from randomly selected four central rows and was recorded as number of plants per meter row length. The spike length was measured, from five randomly selected plants starting from the base to the uppermost part of the spike-using centimeter. Thousand grains weight from each plot were weighed and recorded as thousand-kernel weight. Above ground biomass yield was measured by harvesting from net plot at ground level, sun dried and weighed using spring balance and recorded in t ha^{-1}. Similarly, grain yield was measured by taking the weight of the grains threshed from the net plot of each plot after adjusting the grain to 12.5% moisture content and was recorded in Kg ha^{-1}. The straw yield was determined by subtracting the grain yield from total aboveground biomass and was recorded in t ha^{-1}. Grain of 250 g samples was taken to measure grain protein content using Infratec-1241-grain analyzer at Amhara Agricultural Research Institute grain quality laboratory. Analysis of variance was conducted using SAS system (SAS, 2002). The over years combined mean grain yield of durum wheat for each location was subjected to partial budget analysis for economic feasibility (CIMMYT, 1988).

2.4. Soil Sample Collection and Analysis

Before planting, soil samples were collected using an auger at a plow depth of 0 to 20 cm for assessing the status of essential soil properties. The hydrometer method was used to determine the particle size distribution of the soil sample (Bouyoucos, 1962). The pH of the soil was analyzed by diluting the sample with a water at the ratio of 1:2.5 and measuring it using a glass electrode pH meter (Murphy, 1968). The Micro-Kjeldahl method (Jackson, 1973) was used to quantify the total nitrogen content, while the Olsen methods was used to determine the phosphorus content (Olsen *et al.,* 1954). The volumetric approach was used to calculate the organic carbon content (Walkley & Black, 1934). The available organic carbon was multiplied by 1.72 to estimate the organic matter contents of the testing locations.

2.5. Partial Budget Analysis

To determine economically profitable treatments, partial budget analysis was performed following the procedure of the International Maize and Wheat Improvement Center (CIMMYT, 1988). The cast of nitrogen and phosphorus were considered as variable costs. Other production costs, such as land renting, labor for land preparation, weeding, harvesting, trashing and cleaning were considered as fixed costs across treatments. The value of grain and straw yields were considered as an output for analysis. The local costs of UREA and DAP fertilizer were ETB 11.04 kg^{-1} and 15.61 kg^{-1}, respectively while wheat grain price was 20 ETB kg^{-1}. The grain yield was adjusted downward to 10% to reduce the yield gap between experimental plots and farmers` field. Finally, total variable cost (TVC), gross benefit (GB), net benefit (NB), and marginal rate of return (MRR) were calculated as follows:

1. Total variable cost (TVC) was the total costs of individual costs that vary from treatment to treatment.

$$\text{TVC (ETB)} = \sum_{i=1}^{n} \text{C1} + \text{C2} + \text{C3} \ldots\ldots\ldots\ldots\ldots \text{Cn} \qquad (1)$$

Where, C1, C2, C3… Cn, are variable costs during the experimental years

2. Gross benefit (GB) was the gross benefit for each treatment calculated by multiplying the grain

price by the adjusted grain yield.

$$GB\ (ETB) = \sum_{i=1}^{n} U1 + U2 + U3 \ldots\ldots\ldots\ldots\ldots\ldots Un \quad (2)$$

Where, U1, U2, U3…. Un are field benefits obtained in and experiment

3. Net benefit (NB) was calculated by subtracting the total costs from the gross benefits.

$$NB\ (ETB) = GB\text{-}TVC \quad (3)$$

4. Marginal rate of return (MRR) was the marginal net benefit calculated as the change in net benefits divided by the marginal cost.

$$MRR\ (\%) = \frac{NBT2 - NBT1}{TVCT2 - TVCT1} x100 \quad (4)$$

Where T2 and T1 are consecutive treatments, (T) arranged in ascending order based on their TVC after excluding treatments with low NB and high TVC.

3. RESULTS AND DISCUSSION

3.1. Initial Soil Properties

The soil type is Nitosols at Koga irrigation scheme, while Fulivisols at Rib irrigation scheme. The soil texture class at Koga irrigation scheme is clay loam with a particle size distribution of clay 55%, silt 23% and sand 22% (Table 1). While the soil texture at Rib irrigation scheme is clay loam with a particle size distribution of clay 40 %, silt 35% and sand 25 percent. The pH of the soil was weakly acidic in Rib and strongly acidic in Koga (Mamo et al., 2001). This showed that different measure has to be taken to reduce soil acidity at the Koga irrigation scheme rather than at the Rib. In comparison to Rib irrigation scheme, Koga has a lower soil organic carbon concentration (Walkley & Black, 1934) which might necessitate the use of an integrated soil management approach rather than using inorganic fertilizer alone. Total nitrogen is low in Koga and medium in Rib, as shown in Table 1 (Bashir *et al.,* 2015). According to Jones (2002), available phosphorus is medium in Rib and low in Koga. In general, nitrogen and phosphorus are the primary yield-limiting factors for crop production in the area. Nevertheless, the Rib irrigation scheme is better in terms of soil fertility levels than Koga.

Table 1. Soil physicochemical properties of testing sites

	Site		Interpretation		Reference
Soil properties	Koga	Rib	Koga	Rib	
Sand%	22	25			
silt%	23	35			
clay%	55	40			
PH	5.15-5.2	5.7-5.9	strongly acidic	WA	(Mamo et al 2001)
O_C (%)	1.6-1.8	2.2-2.4	low	Medium	(Walkley & Black, 1934)
Total nitrogen	0.10-0.11	0.16-0.17	low	medium	(Horneck *et al.,* 2011)
AVP (mg kg^{-1})	9-11	17-19	low	medium	(Olsen *et al.,* 1954)

*Note: *AVP = available phosphorus; O_C = Organic carbon; WA = weakly acidic*

3.2. Data Analysis in Combined Over Locations

Before proceeding for combined analysis of variance, data were preliminary analyzed to ensure certain conditions. Homogeneity of variance was assessed following Bartlett's test procedure for equality of variances. In doing so, data for locations (Koga and Rib) were not homogenous and sites within location were independently analyzed to give acceptable recommendation (SAS, 2002).

3.3. Effect of N and P Rates on Growth and Yield of Durum Wheat

The analysis of variance for grain yield showed that significant ($P<0.05$) differences between different levels of nitrogen and phosphorus were recorded in Koga and Rib irrigation scheme (Table 2 and 3). In Koga, plant height was significantly ($P<0.05$) affected by sites, the main effects of nitrogen

and phosphorus rates (Table 2). Effective tiller was highly significantly (*P<0.01*) affecting the main effects of nitrogen and phosphorus fertilizer. Grain yield and straw yield only significantly (*P<0.05*) affected by the main effect of nitrogen and phosphorus rates. The protein content of the grain was significantly (*P<0.05*) affected only by the main effect of nitrogen rate. However, most of the growth and yield parameters of durum wheat were not significantly (*P>0.05*) influenced by nitrogen*site, phosphorus*site and nitrogen*phosphorus interactions. In most scenarios, the main effects of nitrogen and phosphorus meaningfully improved the yield and growth variables of durum wheat. This might be due to the fact that soil of the testing site was initially deficient in major yield-limiting nutrients as depicted in Table 1.

Table 2. Mean squares of analysis of variance for different sources of variations on growth and grain yield of durum wheat in Koga irrigation scheme

Source of variation	DF	PH (cm)	Effective tiller	Spike length (cm)	Seeds per spike	TSW (g)	Grain yield (Kg ha^{-1})	Straw yield (t ha^{-1})	Protein Content (%)
Nitrogen (N)	3	2021*	2893**	13.68**	379.1**	506.9*	58955768*	19.30*	69.59*
Phosphorus (P)	2	547.8*	813.9**	3.04	79.69	102.2	74218983*	1.23*	0.21
Replication (Rep)	2	75.58	15.6	0.136	0.948*	8.086	391428	0.51	1.71
Sites (St)	1	137.1	189.1	2.275	10.03*	6.084	200835	0.22	0.17
N*St	3	58.22	135.8	0.537	2.621	8.716	138052	1.17	0.18
P*St	2	10.66	120.1	0.115	68.44	3.034	936773	0.08	0.02
N*P	6	19.1	113.9	0.425	13.2	3.23	465756	0.98	0.26

*Note:DF=Degree of freedom, TSW=thousand seed weight,**highly significant at P<0.01, *significant at P<0.05, ns=not significant at P≥0.05*

In Rib, the analysis of variance showed that the main effect of N and P rates significantly (*P<0.05*) affected the grain yield of durum wheat (Table 3). Year was significantly (*P<0.05*) affecting the plant height and effective tiller of durum wheat. This might be because of the variation of some climate variables such as temperature and rainfall between years. Sites were significantly affected the plant height, panicle length and spike length. This might be due to the variation of soil nutrients across sites. Plant height significantly (*P<0.05*) influenced by N*St and P*St Interactions due to the variation in soil nutrients. Grain yield and biomass yield also significantly (*P<0.05*) affected by the main effect of N and the interaction N*ST.

Table 3. Mean squares of analysis of variance for different sources of variations on growth, grain yield and protein content of durum wheat at Rib irrigation scheme

Source of variation	DF	PH (cm)	Effective Tiller (m^2)	Spike length (cm)	Seeds per spike	TSW (g)	Grain yield (Kg ha^{-1})	Straw yield (t ha^{-1})	PC (%)
Nitrogen (N)	3	5115.1**	4481.5**	22.8*	955.2**	684.09*	83723091.3*	27.39*	77.30*
Phosphorus (P)	2	458.42*	540.51*	2.94*	114.72*	84.354*	7683448.5*	0.14	0.17
Replication (REP)	2	3.4811	9.4067	0.08	136.45*	68.796	97702.5	0.33	0.36
Year (YR)	1	468.72*	6219.3*	64.1	384.81	229.02	1580463.5	10.28	147.1
Sites (ST)	1	248.06*	619.8*	7.16*	46.014	0.0011	244551.8	4.71	0.36
N*ST	3	84.264*	407.54*	0.13	13.498	37.22	218483.8*	0.88	147.01
P*ST	2	1.39*	163.19	0.09	95.995	1.9469	27101.7*	0.69	0.04

N*P	6	25.361	58.572	0.38	2.9453	6.6054	1909804.1	0.55	0.99

*Note: Plant height *TSW = thousand seed weight, ** = highly significant at P<0.0, * = significant at P<0.05, DF = Degree of freedom, PC = Protein content*

Analysis of variance revealed that nitrogen and phosphorus rates were significantly (*P<0.05*) affected the growth, production, and yield components of durum wheat at both irrigation schemes (Table 4 and 5). In Koga, grain yield, plant height, effective tiller, and spike length were significantly (*P<0.01*) affected by the main effect of nitrogen (Table 4). The highest grain yield (4272.82 kg ha^{-1}), plant height (79.61 cm), effective tiller (64.31), spike length (5.90 cm) and seeds per spike (36.83) were recorded from 276 Kg N ha^{-1}, followed by 184 and 92 kg N ha^{-1}. However, there was no statistically significant difference in biomass yield, grain yield, or thousand seed weight between 276 and 184 kg N ha^{-1}. The unfertilized control had the lowest grain yield (1214.2 Kg ha^{-1}), plant height (62.12 cm), effective tiller (42.77 cm), spike length (4.74 cm), and seeds per spike (29.27). Plant height, effective tiller, and spike length increased linearly as nitrogen increased from zero to 276 kg ha^{-1}.

In Rib, the highest plant height (99.28 cm) was at 276 Kg ha^{-1} of nitrogen fertilizer rate (table). Likewise, effective tillers (80.022) and spike length (6.3 cm) were significant (*P<0.05*) and superior at 276 Kg ha^{-1} of nitrogen fertilizer (table 5). Grains yield (4674.73 Kg ha^{-1}) were also the highest at 276 Kg ha^{-1} of nitrogen fertilizer and significant(*P<0.05*) to 184 Kg ha^{-1} in all measured variables except the number of seeds per spike. In contrast, the lowest plant height (70.66 cm), effective tiller number (53.8), number of seeds per spike (37.91) and grain yield (1091.2 Kg ha^{-1}) recorded from unfertilized control. N rate at 184 kg ha^{-1} showed the highest plant height (89.64 cm), effective tiller number (72.26), and seeds per spike (42.86) following 276 Kg ha^{-1} of nitrogen fertilizer. As N rates climbed to 276 Kg ha^{-1}, grain yield continued to rise. This suggests that production increases beyond 276 Kg N ha^{-1} may have been possible. The results were in accordance with Belete, *et al.* (2018) who explained plant height, panicle length, and other growth parameters increased with N rates increased beyond 120 kg ha^{-1}. Similar result was reported by Channabasavanna & Setty (1994) who explained the increase in yield attributing characters were resulted from nitrogen application, which leads to greater dry matter production and accumulation. In other similar studies, Saeed *et al.* (2012) showed that N enhanced internodes length, which ultimately resulted an increased plant height and enhanced the overall vegetative growth of bread wheat. In conformity with this result, Desta & Almayehu (2020) suggested that the tallest plant height (90.42 cm) was obtained from 115 kg ha^{-1} N rate and the shortest plant height (86.51 cm) was recorded from the unfertilized plot. This is mainly because of the availability of N, which support maximum vegetative growth of the durum wheat.

Table 4. Growth, yield and yield component of durum wheat in response to nitrogen and phosphorus rates at Koga irrigation scheme

Treatments	Plant height (cm)	Effective tiller (mrl)	Spike length (cm)	Seeds Per spike	TSW (g)	Grain yield (Kg ha^{-1})	Straw yield (t ha^{-1})	Protein Content (%)
N (kg ha^{-1})								
0	62.12^{d}	42.77^{d}	4.51^{d}	29.27^{c}	42.39^{c}	1214.20^{c}	3.13^{c}	8.49^{d}
92	70.68^{c}	52.14^{c}	4.94^{c}	34.27^{b}	47.21^{b}	3311.61^{b}	3.98^{b}	9.57^{c}
184	75.36^{b}	56.32^{b}	5.52^{b}	35.09^{ab}	49.13^{ab}	4172.11^{a}	4.58^{a}	10.64^{b}
276	79.61^{a}	64.31^{a}	5.91^{a}	36.83^{a}	51.17^{a}	4272.82^{a}	4.75^{a}	11.72^{a}
Sig	*	*	**	**	*	*	*	*
P_2O_5 (kg ha^{-1})								
0	68.34^{b}	49.77^{c}	4.95	34.93	47.29	2877.07^{b}	3.94	10.17
46	72.45^{a}	53.88^{b}	5.24	34.23	48.2	3330.94^{a}	4.18	10.09

92	75.03[a]	58..06[a]	5.45	34.93	48.82	3519.32[a]	4.22	10.04
Sig	*	*	ns	ns	ns	*	ns	ns
CV (%)	9.33	14.83	12.49	13.8	10.78	8.9	16.34	6.98

*Note: *TSW=thousand seed weight, **=highly significant at P<0.01, *=significant at P<0.05, ns=non-significant, CV=coefficient of variation, mrl=meter per row length*

Table 5. Growth, yield and yield component of durum wheat in response to N and P, at Rib irrigation scheme

Treatments	Plant height (cm)	Effective tiller	Spike length (cm)	Seeds per spike	Thousand seed weight (g)	Grain yield (kg ha^{-1})	Biomass (t ha^{-1})	Protein Content (%)
N (kg ha^{-1})								
0	70.67[d]	53.81[d]	4.50[d]	34.01[c]	37.92[c]	1091.21d	3.12[c]	7.72[d]
92	84.72[c]	63.01[c]	5.38[c]	37.95[b]	43.24[b]	2388.73c	4.11[c]	9.19[c]
184	89.64[b]	72.268[b]	5.78[b]	42.87[a]	46.38[a]	3442.52b	4.70[b]	10.21[b]
276	99.28[a]	80.02[a]	6.37[a]	45.61[a]	47.73[a]	4674.73a	5.21[a]	11.14[a]
sig	*	*	**	*	*	**		*
P_2O_5 (kg ha^{-}								
0	82.68[b]	64.12[b]	5.25	38.55	42.56	2456.75c	4.35	9.61
46	86.83[a]	68.43[a]	5.53	40.13	43.68	3005.69b	4.30	9.59
92	88.72[a]	70.72[a]	5.74	41.64	45.2	3235.41a	4.35	9.49
sig	*	*	ns	ns	ns	*	ns	ns
CV (%)	9.5	12.41	13.67	15.23	11.89	15.89	13.56	10.52

*Note: *TSW= thousand seed weight, ** = highly significant at P<0.01, * = significant at P<0.05, CV=coefficient of variation, ns =non-significant*

Plant height, effective tiller, and grain yield of durum wheat showed significant (*P<0.01)* differences in response to the main effect of phosphorus in both irrigation scheme (table 4 and 5). Plant height (75.03 cm), effective tiller (58.06), and grain yield (3519.32 Kg ha^{-1}) were the highest at 92 Kg P_2O_5 ha^{-1} of phosphorus at Koga irrigation scheme (Table 4). Plant height and grain yield obtained from 92 Kg P_2O_5 ha^{-1} were statistically at par with the grain yield obtained from 46 Kg P_2O_5 ha^{-1}. The unfertilized control had the lowest grain yield and other growth parameters in durum wheat. In Rib, plant height, effective tiller and grain yield of durum wheat showed significantly *(P<0.05)* difference in response to phosphorous rates (table 5). The highest plant height (88.72 cm), effective tiller (70.72) and grain yield (3235.41 kg ha^{-1}) were recorded at 92 Kg ha^{-1} of P_2O_5 although, statistically at par with 46 Kg ha^{-1} of P_2O_5 in many growth parameters. The lowest yield and other growth parameter recorded on unfertilized control. Plant height, effective tiller, and grain yield increased with an application of phosphorus, since, numerous physiological activities; including photosynthesis, energy storage and transfer, respiration, cell growth and division depend on phosphorus. Thousand seed weight and protein content did not show significant differences to the main effect of different levels of phosphorus. This showed that the effect of phosphorus in increasing protein content is low. Our results were in conformity with Anwar *et al.* (2021) who reported that phosphorus application at 90 Kg ha^{-1} produced the highest grain yield (3944 kg ha^{-1}) and harvest index (38.8%) but not protein content. In other similar study, Stifanova *et al.* (2022) explained that phosphorus source fertilization had a significantly lower effect in improving quality traits of Durum wheat. concurrently, Saeed et al. (2012) explained maximum plant height (92.6 cm), number of spikes meter^{-2} (363), spike length (11.8 cm), number of grains spike^{-1} (45), biological yield (13056 Kg ha^{-1}), and grain yield (3991 Kg ha^{-1}) recorded at 90 Kg ha^{-1} of phosphorus. In the same way thousand grains weight (41.21 g) and harvest index (38.8%) was the height at 90 Kg ha^{-1} P_2O_5. In other suimilar studies Boukhalfa *et al.* (2015) reported that grain yield, the number of spikes m^2, number of grains spike^{-1}, N content, and

straw yield increased with the phosphorus uptake. Bashir *et al.* (2015) demonstrated that maximum grain yield (4172.11 Kg ha^{-1}) produced from 100 Kg ha^{-1} P_2O_5 followed by 125 Kg ha^{-1} P_2O_5.

The quality parameters of durum wheat such as the thousand seed weight and protein content showed a significant (*P<0.05)* difference to the main effect of nitrogen but not to phosphorus at Koga irrigation scheme (Table 4). The highest thousand seed weight (51.17 g) and protein content (11.72%) were recorded at 276 Kg N ha^{-1} followed by 184 kg N ha^{-1} with thousand seed weight (48.85 g) and protein content (10.64%). Both are statistically at par in terms of thousand seed weight. The N level below 92 kg ha^{-1} showed significantly (*P<0.05)* lower thousand seed weight compared to the highest level. The lowest thousand seed weight (44.2g) and protein content (8.49 percent) recorded from the control plots. In the same way, the protein content showed a significant (*P<0.01)* difference in response to the main effect of nitrogen fertilizer (Table 4). As the rate of N application increased, grain protein content grew up. The highest protein content of 11.14% was recorded at N 276 Kg ha^{-1}, followed by 184 Kg ha^{-1}.

In addition to ANOVA, regression analysis was performed to realize the response of grain yield in response to N and P rates (Figure 2 and 3). In the Koga irrigation scheme, the response of grain yield to N rate was highly significantly (*P <0.01)* quadratic while response to phosphorus was significantly *(P < 0.01)* linear. Maximum grain yield (4442.911 Kg ha^{-1}) was obtained at 224.91 Kg ha^{-1} of nitrogen (Figure 2). Increases in N rate above 224.91 Kg ha^{-1} will not result in increased grain yield and will lead to nutrient wastage. However, phosphorus is significantly linear and could not be determined with the regression formula.

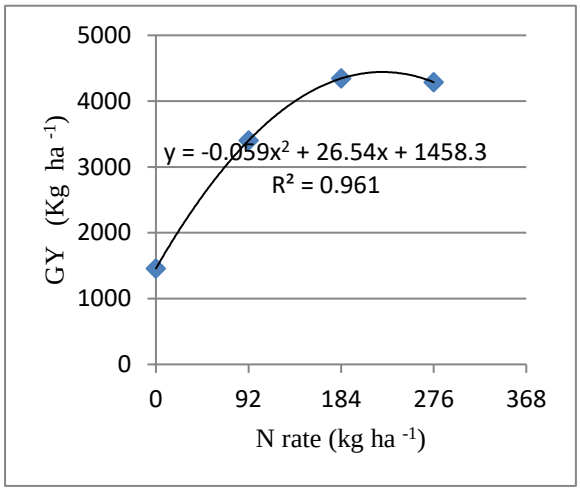


Figure 2: Grain yield response to N rate

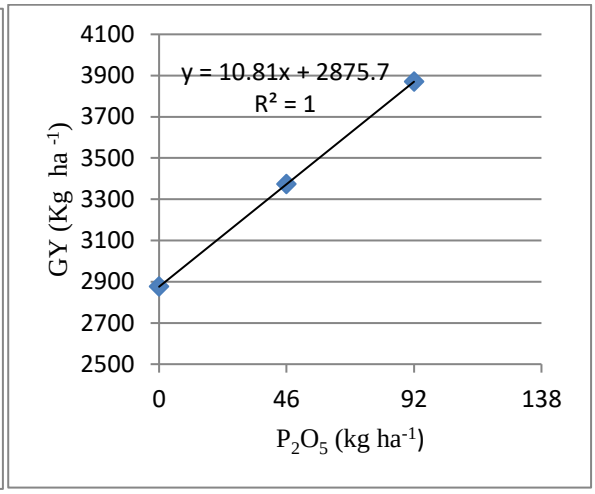


Figure 3: Grain yield response to phosphorus rate

In the Rib irrigation scheme, grain yields strongly *(P< 0.0001)* linear to N rate while it was considerably (P< 0.0479) quadratically responded to P rates (Figure 4 and 5). Therefore, estimated maximum grain yield (3246.7 Kg ha^{-1}) was obtained at 103.2 Kg ha^{-1} P_2O_5. Further raising the rate P_2O_5 over 103.2 Kg ha^{-1}will not result in an increase in grain yield and leads to wastes of fertilizer. This demonstrated how the growth and quality of durum wheat in both locations positively influenced by the balanced usage of nitrogen and phosphorus fertilizer. The result is in line with Shazma *et al.* (2016) who concluded wheat variety produced higher grain yield when treated with 125 Kg N ha^{-1} and 90 Kg P ha^{-1}. Panayotova *et al.* (2017) also reported that combined application of 120 kg ha^{-1} N and 80 kg ha^{-1} was the optimal rate with the highest level of grain yield. Simultaneously Meles (2017) conclude that the released variety HAR1685 had high grain yield potential, strong stems, medium plant height, heavier kernel weight, higher harvest index, and shorter maturing period in responsive to the interaction of higher N and P rates. In other similar studies Chen *et al.* (2020) recommended that fertilizer rate of N 240 Kg ha^{-1} and P 150 Kg ha^{-1} as the optimal nitrogen-phosphorus regime in the North China Plain, which can maintain higher crop yield while lower environmental risk. In parallel to this result

Saqib *et al.* (2012) the interaction of nitrogen and phosphorus was significant for lodging score, 1000-grain weight, grain yield and biological yield.

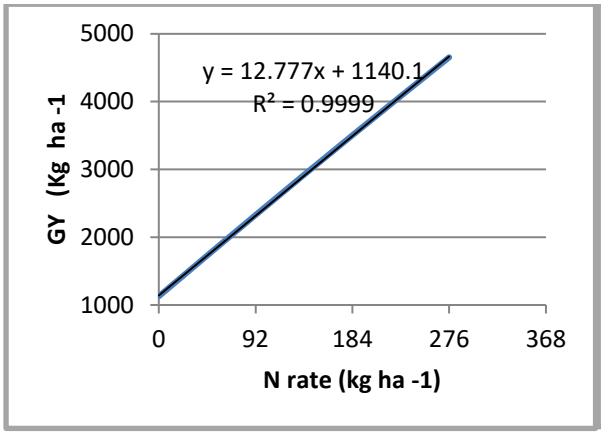


Figure 4: Grain yield response to nitrogen rate

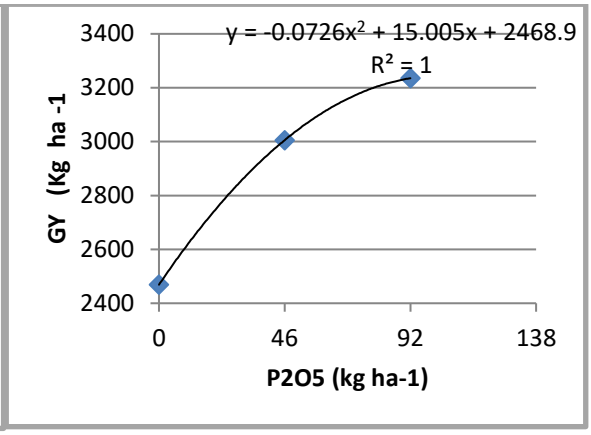


Figure 5: Grain yield response to phosphorus rate

3.4. Partial Budget Analysis

The economic feasibility of each treatment was determined through partial budget analysis. Before going for analysis, the grain yields were adjusted downward by 10% to reduce the yield gap between experimental plots and farmers` field. In both locations, the highest total variable cost (ETB 9969.15) was recorded from N 276 Kg ha^{-1} and 92 Kg ha^{-1} P_2O_5, while the lowest was from unfertilized control. The gross benefit and the net benefit were the highest from N 276 kg ha^{-1} and 92 kg ha^{-1} P_2O_5 treatment combinations in both locations. However, the MRR were the highest from 92 N Kg ha^{-1} and the lowest were from 46 Kg ha^{-1} P_2O_5. However, as far as the net benefit is increased and MRR is above 100%, treatment combination with highest MRR was omitted and the highest net benefit with the higher fertilizer rate could be selected. Therefore, in Koga, the maximum net benefit (ETB 89140.4 ha^{-1}) with acceptable MRR (536%) was recorded at N 184 Kg ha^{-1} and 92 Kg ha^{-1} P_2O_5 rates (Table 6). While in Rib, the maximum net benefit (ETB 97115.61 ha^{-1}) with acceptable MRR (665%) was recorded at 276 Kg ha^{-1} N and 92 Kg ha^{-1} P_2O_5 rates (Table 7). The higher net benefit from the above-mentioned treatments could be mainly attributed to highest grain yield at high level of N and p rate, while the low net benefit was attributed to the low bread wheat yield due to the lack of adequate nutrients. This result is in agreement with various research findings (Demelash *et al.*, 2014; Assefa *et al.*, 2016; Adugna & Haile, 2019), who stated that maximum net benefits and MRR were observed from the highest grain yield resulting from the application of a higher N and P rate.

Table 6. Partial budget analysis for different levels of N and P2O5 at Koga irrigation scheme

N (kg/ ha)	P_2O_5 (kg/ ha)	Adjusted grain yield (kK ha^{-1})	N price (ETB)	P_2O_5 price (ETB)	TVC (ETB)	Grain price (ETB)	Gross Befit (ETB)	Net Benefit (ETB)	MRR (100 %)
0	0	961	0	0	0	19220	19220	19220	-
0	46	1458.26	0	1561.57	1561.57	29165.2	29165.2	27603.6	5.26
92	0	2903.304	2282	0	2282	58066.1	58066.1	55784.1	39.11
0	92	1955.52	0	3123.15	3123.15	39110.4	39110.4	35987.3 D	
92	46	3400.564	2282	1561.57	3843.57	68011.3	68011.3	64167.7	5.36
184	0	3846.856	4564	0	4564	76937.1	76937.1	72373.1	11.38
92	92	3846.856	2282	3123.15	5405.15	76937.1	76937.1	71532 D	
184	46	4344.116	4564	1561.57	6125.57	86882.3	86882.3	80756.8	5.36
276	0	3791.656	6846	0	6846	75833.1	75833.1	68987.1 D	

184	92	4841.376	4564	3123.15	7687.15	96827.5	96827.5	89140.4	5.36
276	46	4288.916	6846	1561.57	8407.57	85778.3	85778.3	77370.8 D	
276	92	4786.176	6846	3123.15	9969.15	95723.5	95723.5	85754.4 D	

*Note: *TVC=total variable cost, ETB=Ethiopian birr, urea cost=11.04 ETB kg^{-1}, DAP cost=15.61 ETB kg^{-1}, wheat grain price =20 ETB kg^{-1}, D=dominated and MRR=marginal rate of return.*

Table 7. Gross income and net profit of different levels of N and P_2O_5 fertilizer at RIB irrigation scheme

N (kg/ha)		Adjusted Grain yield (kg/ha)	N Cost (ETB)	P Cost (ETB)	TVC (ETB)	Grain price (ETB)	Gross Befit (ETB)	Net Benefit (ETB)	MRR (100%)
0	0	1061.47	0	0	0	21229.46	21229.46	21229.46	-
0	46	1230.13	0	1561.57	1561.57	24602.66	24602.66	23041.09	1.16
92	0	2016.1	2282	0	2282	40322.04	40322.04	38040.04	20.81
0	92	1091.76	0	3123.15	3123.15	21835.22	21835.22	18712.07D	
92	46	2430.13	2282	1561.57	3843.57	48602.66	48602.66	44759.09	4.30
184	0	2946.19	4564	0	4564	58923.7	58923.7	54359.7	13.32
92	92	2537.13	2282	3123.15	5405.15	50742.64	50742.64	45337.49D	
184	46	3605.59	4564	1561.57	6125.57	72111.76	72111.76	65986.19	7.44
276	0	3851.72	6846	0	6846	77034.46	77034.46	70188.46	5.83
184	92	3957.96	4564	3123.15	7687.15	79159.16	79159.16	71472.01	1.52
276	46	4756.5	6846	1561.57	8407.57	95129.94	95129.94	86722.37	21.16
276	92	5354.24	6846	3123.15	9969.15	107084.8	107084.8	97115.61	6.65

*Note: *TVC=total variable cost, ETB=Ethiopian birr, urea cost = 11.04 ETB kg^{-1}, DAP cost =15.61 ETB kg^{-1}, wheat grain price =20 ETB kg^{-1}, D=dominance and MRR=marginal rate of return.*

4. CONCLUSIONS

Nutrient depletion is one of the major causes of crop productivity decline in the highlands of Ethiopia. Nitrogen and phosphorus in the form of urea and NPS are the major fertilizers applied to improve the productivity of varieties of crops in the country. In the same manner, application of nitrogen, and phosphorus significantly affected the growth parameter, protein content and yield of durum wheat in both irrigation schemes. All growth parameters and yield of durum wheat showed an increasing trend to the increasing level of nitrogen and phosphorus fertilizer. This indicated that application of nitrogen and phosphorus fertilizer was quite essential in both irrigation schemes. However, locations showed heterogonous errors of variance and location by treatment interaction was statically significant. Hence, location-specific recommendation is reliable than in combined over locations. In Koga, the economically optimum N and P_2O_5 rates were 184 kg ha^{-1} and 902 kg ha^{-1}, respectively. Concurrently, N rate of 276 kg ha^{-1} and 92 kg ha^{-1} P_2O_5 were the economic optimum fertilizer rates in Rib. As a result, it can be concluded that the fertilizer rate 184 kg ha^{-1} of N and 92 kg ha^{-1}of P_2O_5 for Koga and, 276 kg ha^{-1} of N and 92 kg ha^{-1} of P_2O_5 for Rib were recommended for optimum grain yield of durum wheat.

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Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors upon reasonable request

Conflict of interest statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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