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EFFECT OF THE RATE OF N-FERTILIZER APPLICATION ON GROWTH AND YIELD OF WHEAT (*TRITICUM AESTIVUM* L.) AT CHENCHA, SOUTHERN ETHIOPIA

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ABSTRACT: There is little knowledge among farmers on the rate of N-fertilizer application. Therefore, there is a need to determine optimal rate of N-fertilizer application on growth and yield of wheat. Accordingly, an experiment was conducted to evaluate the effect of the rate of N-fertilizer application on yield and yield components of wheat on two locations at Chencha, Southern Ethiopia in 2014 cropping season. The experiment consisted fiver rates (0, 23, 46, 69 and 92 k.gha^{-1}) of N-fertilizer application were arranged in RCBD. The rate of N-fertilizer application had significantly affected days to heading and maturity, plant height, number of tiller, panicle, thousand seed weight, grain, straw and total biomass yields. But the rate of N-fertilizer had not significantly affected harvest index. N applied with the rate of 23, 46 69 and 92 kg ha^{-1}, minimizes the date of heading by 9 days compared with control. Meantime N applied 69 kg ha^{-1} had contributed for 18.9 % in increments in height than no fertilizer applied/control. Fertilizer applied at the rate of 46 kg ha^{-1} was contributed for 27.12 % increment in spike length than N applied 92 kg ha^{-1}, but resulted for 19.7 % reduction compared with N applied 46 kg ha^{-1}.Generally N applied with the rate of 69 kg ha^{-1} had more tillers, thousand seed weight, biomass, straw and grain yield than fertilizer applied 0, 23, 46 and 120 kg ha^{-1}.

Key words: Time of fertilizer application; Rate of fertilizer; Fertilizer; Nitrogen

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INTRODUCTION

Ethiopia is one of the largest producers of wheat in sub-Saharan Africa [1]. Wheat grows mostly in the highlands area of Ethiopian, at altitudes ranging from 1500 to 3000 m [2]. Though Ethiopian agro-climatic condition is suitable for white production, productivity is low (1.3 t ha^{-1}). This is because of depleted soil fertility [3, 4], low levels of chemical fertilizer usage limited knowledge on time and rate of fertilizer application [3-6], and the unavailability of other modern crop management inputs [3].Therefore managing of soil fertility is crucial for improving wheat productivity. Using of fertilizers which, containing N and P are affects wheat yield and quality [7,8]. Especially using of N fertilizer is considered to be a primary means of increasing wheat grain yield in Ethiopia [4,5]. Though appropriate time and rate of N fertilizer application have a number of merits, but there is little knowledge in Ethiopia [3]. Particularly farmers of Chencha woreda have no idea on appropriate rate of N fertilizer application. These resulted for reeducation in both yield and quality of wheat [9]. Therefore, this study was initiated with the following objectives:

1) To evaluate the effect of rate of N-fertilizer application on growth and yield of wheat.
2) To identify the optimum rate of N-fertilizer application on growth and yield of wheat.

MATERIALS AND METHODS

Site Description

These studies were conducted at Dokotsida and Gindogembela Kebeles of Chencha Woreda, in Southern Ethiopia. The woreda is situated at 90 5'N and 390.45'E with an elevation range of 1700- 3100 masl; which are ideal for the production of wheat. The mean annual rain fall varies from 900-1400 mm. The dominant crops growing around the experimental area are enset (*Ensete ventricosum*), wheat (*Triticum aestivum* L.) and Potato (*Solanum tuberosum*) [10].

Experimental Treatments and design

The experiment conducted on the rate of N-fertilizer application; were arranged in factorial RCBD design and replicated four times. The rate of N-fertilizer consists of application (0, 23, 46, 62 and 92 k.gha^{-1}).

Experimental Procedure

Degelo wheat variety was used at 150 kgha^{-1} as a test crop; and the experimental field was prepared by using oxen plow and plowed four times, before planting. Meanwhile DAP fertilizer was used at the rate of 100 kgha^{-1} as source of N and P; and Urea was applied at the rate of 0 , 23, 46, 69 and 92 kgha^{-1} at the knee stage.

Soil Sampling and Analysis

Sixteen random soil samples (0-30 cm depth) from the experimental field were thoroughly mixed to make a composite. The sample was air dried and ground to pass 2 mm sieve and necessary parameters such as soil texture, available P, pH and CEC were determined. For the determination of OC and N 1 mm sieve was used. Soil texture was analyzed by Bouyoucos hydrometer method [11,12]. Available P was extracted with a sodium bicarbonate solution at pH 8.5 following the procedure described by [12]. The pH of the soil was measured potentiometrically in the 1: 2.5 soil: water mixture by using a pH meter and organic carbon was determined following Walkely and Black wet oxidation method [13]. Cation Exchange Capacity (CEC) was determined by Ammonium Acetate method [14].

Data Collection

Phenological data

Days to 50% heading: number of days from sowing up to the date when the tips of the panicles first emerged from the main shoot, on 50% of the plant in a plot.

Days to 90% maturity: number of days from the date of sowing up to the date when 90% of the crop stands in a plot changed to light yellow color.

Growth data

Plant height (cm): It was measured at maturity, from five random plant samples of the harvestable rows, from the ground level to the tip of the spike.

Tillers number (m^{-2}): To determine the capacity of tillering per 1 m^2, 10 x 20 cm area was demarcated and the number of plants existed in that area was counted. Then recounting was done after at flowering on demarked area; because maximum tillers produced during vegetative phase and senescence occurs at maturity [15]. Finally the difference between the first and second count was converted into 1 m^2.

Panicle length (cm): length of the panicle was measured by selecting six plants randomly and measuring from the node (the first panicle branch started) to the tip of the panicle.

Yield and yield components

Total above ground biomass (kg): was measured after sun-drying for two days.

Straw yield (kg): was measured by subtracting grain yield per plot from the total above ground biomass.

Grain yield (kg ha^{-1}): yield from every plot.

Thousand seed weight (g): the seeds were taken from each plot and 1000 seeds counted by hand and then weighted.

Harvest index: the ratio of grain yield to the above ground (shoot) biomass. [HI= Grain yield/Total biomass].

Economic Analysis

For economic analysis, a simple partial budget analysis was employed using CIMMYT approach [16]. For partial budget analysis, the factors with significant effect were considered. The yield was adjusted by subtracting 10 % from average gain yield. Than after, gross yield benefit was obtained by multiplying the adjusted yield by the price of grain (13 birr kg^{-1}). Net benefit was calculated, by subtracting labor cost from gross yield. Finally marginal rate of return (MRR) was obtained, by dividing marginal net benefit to the marginal cost and expressed as percentage [16]. The mean market price of wheat was obtained by assessing the market at harvest (2014 cropping season).

Data Analysis

The various agronomic data were analyzed using the general linear model (GLM) procedures of the SAS statistical software [17] to evaluate the effect of sowing method and time of fertilizer application and their interaction. Least Significant Difference (LSD) test at P≤0.05 was used to separate means whenever there were significant differences.

RESULTS AND DISCUSSIONS

Physicochemical Properties of the Experimental Soil

The analytic results indicated that the experimental soil of Dokotsida and Gindogambla kebeles were textured clay loam and loam respectively. Meantime both kebles having organic carbon content (OC) of 0.95 and 0.78% respectively (Table 1). Accordance with [18], the soil in both locations had high OC, who rated OC between 1.74-2.90% as high. The CEC of the soil were 23.87 cmol kg^{-1} and 23.87 cmol kg^{-1} at Dokotsida and Gindogambla kebeles respectively which, could be considered as medium. Because if CEC value ranges between 25 and 40 cmol kg^{-1} satisfactory response for applied fertilizer [15-18]. According to [12] P rating (mg kg^{-1}), P content of < 3 is very low, 4 to 7 is low, 8 to 11 is medium, and > 11 is high. Thus experimental sites, available P content were medium in both locations. The pH of the soil were 5.88 and 5.23 on Dokotsida and Gindogambla respectively, which is within the range of 4 to 8 suitable for wheat production [19]. Total N of the soil on both locations (0.098 % and 0.070%), are low; as rated [20-23] who rated total N less than 0.15 % as low.

Table 1: Physio-chemical properties of the experimental soil.

Location	Depth (cm)	pH (H_2o)	CEC (cmol kg^{-1})	OC (%)	Total N (%)	Av.P (mg kg^{-1})	Particle size distribution (%)			Textural
							sand	clay	silt	Class
Dokotsida	0-30	5.88	24.6	0.95	0.098	8.4	36	28	36	Clay loam
Gindogambla	0-30	5.23	22.4	0.78	0.070	7.8	26	26	48	Loam

CEC= Cation Exchange Capacity, OC= Organic Carbon, Av.P= Available phosphorous.

Crop Phenology

Days to heading

The rate of N-fertilizer application had a significant (P≤0.001); effect on days to heading.

Fertilizer applied with the rate of 23, 46 69 and 92 kg ha^{-1}, minimizes the date of heading by 9 days compared with control (Table 2). The result in line with the finding of Cock and Ellis (1992) indicated that sufficient nitrogen at right time results in rapid growth and heading. However too little N fertilizes application and excessive N applied at any time resulted in delayed heading, because excessive N kept vegetative growth active and finally resulted in delayed heading and flowering [22].

Table 2: Effect of the rate of N-fertilizer application on wheat phenology.

Treatment	50% Heading	50% Maturity
FR		
0 kg ha-1	58.42a	170.42a
23 kg ha-1	49.33b	163.08bc
46 kg ha-1	50.17b	164.50b
69 kg ha-1	49.33b	164.00bc
92 kg ha-1	50.00b	162.50c
LSD (5%)	1.27	1.81
CV (%)	2.13	0.94

FR= Fertilizer Rate, the same letter in a column of each factor shows a non-significant difference at 5% probability level.

Days to maturity

Days to 90% maturity was significantly affected by the rate N fertilizer application.

Meantime the rate of N fertilizer application had significant (P≤0.001) effect on maturity. Fertilizer applied 23, 46 and 69 kg ha^{-1}hasten date of maturity by 7-days than control and delayed by 2 days than fertilizer applied 92 kg ha^{-1}. These results are in line with [23] who reported that, N fertilization at the rate of 69 kg ha^{-1}significantly affected date of maturity of wheat. These variations on date of maturity of wheat might be, due to shoots maturity directly affected by the rate of fertilizer application [24].

Plant height

The rate of fertilizer application had significant (P≤0.001) effect on plant height.

Fertilizer applied with the rate of 69 kg ha^{-1} had contributed for 18.9 % in increments in height than no fertilizer applied/control (Table 3). This result is major indicator for the height of wheat mainly affected by the rate of fertilizer application [15]. This is because of N fertilizer has plays vital role in vegetative growth and resulted for significant influence on plant height [25]. But non optimal application of N, resulted in significantly reduction on heights [26, 27].

Table 3: Effect of the rate of N-fertilizer application on growth and yield of wheat.

Treatment	pH	SL
FR		
0 kg ha-1	75.00c	3.00d
23 kg ha-1	87.92b	4.83bc
46 kg ha-1	90.17 ab	5.42b
69 kg ha-1	92.47 a	6.75a
92 kg ha-1	86.27 b	3.95cd
LSD (5%)	4.27	1.28
CV (%)	2.13	0.94

PH=Plant Height, FR= Fertilizer Rate, the same letter in a column of each factor shows a non-significant difference at 5% probability level.

Spike length

The rate of N-fertilizer application significantly (P≤0.001) affected spike length of wheat. Fertilizer applied at the rate of 46 kg ha^{-1} was contributed for 27.12 % increment in spike length than N applied 92 kg ha^{-1}, but resulted for 19.7 % reduction compared with N applied 46 kg ha^{-1} (Table 3). These findings are strongly justifies, N fertilizer application by itself do not have significant effect on panicle length of wheat. But the optimum amount of fertilizer application has significant effect on growth of spike length. Similar results have also been reported by [27], higher spike length of wheat achieved by fertilizer applied 69 kg ha^{-1}at knee stage. Meanwhile excessive application of N fertilizer has toxic effect on wheat growth and results for stunted growth and reduced spike length [28].

Yield and yield components

Tillers

The rate of N application significantly (P<0.001) affected the number of tillers.

N applied with the rate of 69 kg ha^{-1}had 46.6 % and 60 % more tillers than N applied 92 kg ha^{-1} and none applied respectively (Table 4). The above result indicated that enhancement in tiller number when N fertilizer applied with optimum amount. Meanwhile the result is agreement with that of [29] who reported higher tillering and maximum survival percentage of tillers with optimum time and rate of N fertilizer application in bread wheat. Agree with the results of this study, reported that stimulation of tillering with optimal application of N might be due to its positive effect on cytokinin synthesis. Generally maximum number of tiller achieved through N fertilizer applied with the rate of 69 kg ha^{-1} [25,29].

Table 4: Effect of the rate of N-fertilizer application on growth and yield of wheat.

Treatment	NT(cm)	TBM(kg ha-1)	SY(kg ha-1)	TSW(g)	GY(Qt ha-1)	HI
FR						
0 kg ha-1	2.00d	10821.5ab	8835.7a	46.79e	17.83e	0.25
23 kg ha-1	3.10c	9600.8bc	6975.8bc	53.17c	26.25c	0.27
46 kg ha-1	4.00b	10414.9abc	7623.2abc	55.17b	27.92b	0.27
69 kg ha-1	5.00a	11770.6a	8445.6ab	57.00a	29.50a	0.29
92 kg ha-1	2.67cd	8908.3c	6689.7c	50.66d	23.85d	0.27
LSD (5%)	0.84	1818.1	1726.5	1.40	1.54	0.06
CV (%)	21.50	22.96	19.25	2.29	5.29	17.85

FR= Fertilizer Rate, NT= Number of Tillers, TBM = Total Bio Mass, SY = Straw Yield, GY = Grain Yield, HI= Harvest Index, the same letter in a column of each factor shows a non-significant difference at 5% probability level.

Total biomass

The rate of N fertilizer application were significantly ($p \leq 0.001$) affected biomass yield of wheat.

Fertilizer applied 69 kg ha^{-1} contributed to 24.3 % and 21.1 % increment in biomass than fertilizer applied 92 and 23 kg ha^{-1} respectively (Table 4). N fertilizer application at optimum amount significantly enhanced biomass yield of wheat [30]. But application of highest level of N resulted in less biomass yield. This might be due to maximum amount of N fertilizer application resulted for lodging. Finally lodging before the translocation of dry matter results for reduction on economic yield, since biomass includes the economic yield [31].

Straw yield

The rate of fertilizer application was significantly ($p \leq 0.001$) affected straw yield of wheat.

The control had 24.3 % more straw than fertilizer applied with the rate of 92 kg ha^{-1} (Table 4). These might be due to the lack of N nutrient in control, resulted for less cytokinin synthesis and minimum photosynthesis [27]. Meanwhile less photosynthesis resulted to little grain filing and maximize straw production [32]. But excessive N fertilizer application had toxic effect on crop and resulted for less straw and grain yield production [33].

Thousand Seed weight

Thousand seed weight is an important yield determining component and reported to be a genetic character that is influenced least by environmental factors [34]. The analysis of variance showed that the rate of N fertilizer application had significant ($p \leq 0.001$) effect on thousand seed weight. N applied 46 kg ha^{-1} had 15.2 % more and 3.2 % less thousand seed weight than control and N applied 69 kg ha^{-1} respectively (Table 4). This result is agreed with that of Channabasavanna and Setty who reported positive response of rice grain weight to N application. However, in contrast to the finding of this study, [35] reported no significant effect of application of different rates of N fertilizer on thousand seed weight of bread wheat. But the optimum amount of N fertilizer gave better grain weight [35-37].

Grain yield

Grain yield of wheat was highly significantly ($P \leq 0.001$) influenced by the rate of N fertilizer rate application.

Fertilized applied with rate of 46 kg ha^{-1} had 5.4 % less and 36.1 % more grain yield than fertilizer applied 69 kg ha-1and control respectively (Table 4). In line with the result of this study, [37] reported that application of different levels of N significantly affected grain yield of tef on farmer's field. This is because of well-balanced supply of N at optimal amount, results in higher net assimilation rate and increased grain yield [38]. According to this study to maximizing the grain yield of wheat, applying of 69 kg ha^{-1} N is appropriate, because proper rate and time of application are critical for meeting crop needs. In agreement with the results of this study, indicated that split N application 69 kg ha^{-1} is effective in attaining higher grain yield of wheat [39-41].

Harvest index

The rate of N fertilizer application had not significantly affected harvest index (Table 4).

Correlation of grain yield with yield and yield components

Grain yield considered as dependent, whereas plant height, growth rate, tillers, spike length, thousand seed weight, straw yield, total biomass and harvest index were taken as explanatory variables (Table 5).

Grain yield was positively and significant ($P < 0.001$) associated with plant height, tillers, spike length, total biomass, straw and grain yield, thousand seed weight and harvest index, r=0.98, 0.87, 0.88, 0.50, 0.32, 0.97 and 0.35, respectively. Similar correlations were reported in barley by [39,42]. On the other hand, grain yield was associated negatively with day to heading and maturity, r=--0.89*** and -0.78*** respectively; which was in line with the report of [23] on bread wheat [42].

Table 5: Correlation between yield and yield components of wheat.

X	DH	DM	PH	TN	SL	TBM	SY	GY	TSW	HI
DHD	1	0.96***	-0.85***	-0.64***	-0.66***	-0.27*	-0.09ns	-0.89***	-0.8***	-0.36***
DM		1	-0.79***	-0.53***	-0.55***	-0.18 ns	-0.02ns	-0.78***	-0.65***	-0.33***
PH			1	0.86***	0.90***	0.47***	0.29*	0.98***	0.94***	0.34***
TN				1	0.96***	0.71***	0.58***	0.87***	0.91***	0.25*
SL					1	0.65***	0.52***	0.88***	0.93***	0.27*
TBM						1	0.94***	0.50***	0.54***	0.15 ns
SY							1	0.32*	0.36***	0.01 ns
GY								1	0.97***	0.36**
TSW									1	0.35**
HI										1

ns = not significant, * ** &*** significant at 0.05, 0.01and 0.001 respectively, DHD= Date of Heading, DM= Date of Maturity, TN= Tillers Number, SL = Spike Length TBM = Total biomass, GY = Grain Yield, SY = straw yield, TSW = Thousand Seed Weight and HI= Harvest Index

Partial Budget Analysis

The net benefits obtained in response to N fertilizer applied 23, 46 and 69 kg ha^{-1} were 40005, 43305 and 47625 birr respectively. The higher marginal rate of return with least cost was obtained from 46 kg ha^{-1}, but further earning on N applied 69 kg ha^{-1}. Because the marginal rate of return was above the minimum level (100%). According to [16] the recommendation is not necessarily based on the treatment with the highest marginal rate of return compared to that of neither next lowest cost, the treatment with the highest net benefit, and nor the treatment with the highest yield. The identification of a recommendation is based on a change from one treatment to another if the marginal rate of return of that change is greater than the minimum rate of return. Thus, 69 kg ha^{-1} N fertilizer applied at thirty days after planting is economically beneficial compared to the other treatments.

Table 6: Partial budget analysis of wheat as influenced by N fertilizer rate.

Treatment	Av.Y (q ha^{-1})	ADTY (q ha^{-1})	GFB (birr ha^{-1})	Total variable cost (Birr ha^{-1})	Net benefit (Birr ha^{-1})	MRR (%)
0	20.75	18.67	28,005	0	28,005	
23	30.75	27.67	41,505	1,500	40,005	80
46	33.75	30.37	45,555	2,250	43,305	440
69	37.5	33.75	50,625	3,000	47,625	576
92	24.25	21.83	32,337.50	4,500	27,837.50	-

Av.Y= Average Yield, ADTY=adjusted yield, GFB= Gross Field Benefit, DFM=Days of Farm Management, MRR=Marginal Rate of Return

CONCLUSION

In this study it was found that, the rate of N-fertilizer application had significant effect on growth and yield of wheat. Especially 69 kg ha^{-1} N applied, gave both maximum biological and economic yield. Meantime fertilizer applied 69 kg ha^{-1} had acceptable MRR (576%); and net benefit 47625 birr ha^{-1} from grain yield. Thus, it is possible to recommend that, N application 69 kg ha^{-1} is effective in attaining higher grain yield and economic benefit of wheat in the trail area. However, it is advisable to undertake further research across soil type, years and locations to draw sound recommendation on a wider scale.

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