Optimizing N fertilizer use for sesame under rain fed and irrigation conditions

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Abstract

Inappropriate use of fertilizers is one of the major production constraints in sesame. Studies to optimize the use of N fertilizer on sesame were conducted at Humera Agricultural Research Center (HuARC) under rain fed and irrigation conditions. Thirteen (13) N doses were evaluated in a Randomized Complete Block Design (RCBD) during 2016, 2017 and 2018. In the rain fed condition; results showed higher number of days to 50% flowering on the higher N application. The 31-121.5 kg N ha⁻¹ have scored higher seed yield, where the lower (18 kg N ha⁻¹) and higher (156 kg N ha⁻¹) N doses scored lower seed yield. In the irrigation condition; higher N application rate prolonged the flowering time to some extent and days to 90% maturity was reduced as N rate increased. Heavier seed weights and maximum seed yield were recorded on 64 and 75 kg N ha⁻¹ and the lower N doses scored low seed yield. Agronomic efficiency of N fertilizer (N-AE) was higher on 64 kg N ha⁻¹ under both growing conditions. The partial budget analysis revealed that 64 kg N ha⁻¹ (rain fed) and 75 kg N ha⁻¹ (irrigation) had the higher net profit, MRR and residual ranking. Therefore, for the greater sesame productivity 64 kg N ha⁻¹ has to be recommended for rain fed and 64 to 75 kg N ha⁻¹ for the irrigated sesame.

Key words: Sesame, N fertilizer, agronomic efficiency and seed yield

1. Introduction

Sesame (*Sesamum indicum* L.) is one of the most ancient oil seed crop in the tropics, where Ethiopia is considered to be the center of cultivation [1,2]. Origin of sesame has been a matter of discussion for a long but it was presumed to have originated in Africa and later spread to Asia [3]. Sesame is an important source of high quality oil and protein [4,5], the oil has excellent stability due to the presence of natural antioxidants (sesamol and sesamin) [6] and these lignans protect from oxidative rancidity. Sesame, the chief source of “queen oil” has the capacity

to set seed and yield remarkably well under high temperatures, it has a deep taproot for extracting moisture and nutrient from lower soil layers and succeeding on as little as 200 -400 mm of rain during the growing season [4]. In Ethiopia, sesame is a main source of foreign currency of the agricultural commodities next to coffee. Inappropriate use of fertilizers is one of the major production constraints in sesame [7,8]. Fertilizer applications to sesame is crucial for better yield and high seed quality [9]. HuARC [10] reported that application of 100 kg N/ha produced higher seed yield under rain fed conditions. Moreover, higher seed yield (1315.09 kg/ha) was recorded by application of 150 kg N/ha, while lower seed yield (554.17 kg/ha) recorded from 50 kg N/ha [11]. In Ethiopia, application of 120 kg/ha NPK plus 50 kg urea (42 kg N/ha) gave 32% yield increment over zero fertilization under rain fed condition [10]. Other study in the area witnessed that higher seed yield (744.3 kg/ha) was recorded from application of 100 kg/ha DAP and 50 kg/ha urea (41 kg N/ha) in Humera [12]. Under irrigation condition, application of 100 kg N/ha produced higher seed yield Bahar et al. (2011). Moreover, higher seed yield (1315.09 kg/ha) was recorded by application of 150 kg N/ha [7]. In the other case, higher seed yield of sesame (769 kg/ha) was recorded when 44 kg N/ha was applied [9]. El-Sherif [8] concluded that application of 142 kg/ha N was economical under irrigation condition. In general, Zenawi and Mizan [13] reviewed that the optimum N fertilizer application for the potential areas varies from 50-100 kg N/ha based on the soil type and moisture availability status. However, 41 kg N/ha is the common practice in the study area (potential area of sesame) where the world experience is 50-100 kg N/ha. Therefore, objective of the study was to optimize N fertilizer use for sesame under rain fed and irrigation conditions.

2. Material and methods

2.1. Description of the Study Area

A field experiment at Humera Agricultural Research Center (HuARC) western Tigray, which is located at latitude of 14°15' N, longitude of 36°37' E and elevation of 608m to optimize N fertilizer use in sesame was conducted. The agro-ecology of the location is described as hot to warm semiarid plain with mean temperature of 29°C, annual mean rainfall of 500 mm and chromic vertisol.

2.2 Treatments and Experimental Design

The field experiment was done in Randomized Complete Block Design (RCBD) with three replications in 2016, 2017 and 2018 production seasons. The experimental area included five rows with the length of five meter. The path between blocks and plots were 2 m and 1m, respectively. The treatments consisted of 13 N doses; 18, 29.5, 41, 52.5, 64, 75.5, 87, 98.5, 110, 121.5, 133, 144.5 and 156 kg N ha⁻¹. Seeding was done in rows with row spacing of 40 cm and seedlings were thinned to achieve 10 cm space between plants when the plants attained a height of 5 cm. The 41 kg N/ha was used as standard check (research recommendation for rain fed [12] and blanket recommendation for irrigated sesame). Setit-2 variety from HuARC was used as a test variety, 38 kg P/ha and 7 kg S/ha were applied from NPS blended fertilizer. The NPS fertilizer was applied during plating and urea (N doses) were applied in two splits (1/2 during planting and the remaining at flower initiation). The field was ploughed and harrowed three times to obtain fine tilt, thereafter marked into plots. Early January and early July were the planting dates for the irrigated and rain fed sesame, respectively. Ridge and furrow were prepared for the irrigated sesame and seed were planted in mid pint of the ridges. Surface irrigation technique was used to water the irrigated sesame. All agronomic practices were applied to all experimental units uniformly. Border rows and 0.5 m from both sides of each row were used as buffer zones to minimize the effects of external factors. About 500 g composite top soil samples (0–20 cm) were collected using auger before planting to determine physicochemical properties of the soil of the experimental sites (Table 1). Average rainfall and temperature data of study site were presented (Figure 1).

Table 1 Physical and chemical properties of the soil of the study area (average values of 2016-2018).

Soil parameters	Measurements	Critical levels	Method of Analysis	References
pH-H ₂ O	7.75	6.6 – 7.3	pH meter (1:2.5)	[14]
OC (%)	1.01	<2	Walkley and Black	[15]
CEC (meq/100 g soil)	64.5	<25	Ammonium acetate	[16]
TN (%)	0.08	<0.2	Kjeldahl	[15,17]
Av.P (ppm)	7.19	<10	Bray P1	[16]
S (ppm)	10.5	<20	turbidity method	[14,18]
Clay content (%)	68		Hydrometer method	[19]
Silt content (%)	13		Hydrometer method	[19]
Sand content (%)	19		Hydrometer method	[19]

2.3 Data collection

Phenological data: 50 % flowering and 90% maturity were the two important phenological traits recorded.

Growth parameters: number of branches per plant and plant height were recorded.

Yield and yield components: number of capsules per plant, number of seeds per capsule 1000 seed weight and seed yield were collected. Agronomic N use efficiency was also calculated.

Nitrogen use efficiency can be measured in a variety of ways; the most basic level is agronomic efficiency (AE) of fertilizer application [20], which is measured as the increase in seed yield divided by the rate of application (eq1). Agronomic efficiency (AE) is expressed as the additional amount of economic yield per unit of nutrient applied [21].

$$N - AE = \frac{Yield\ F, kg - Yield\ C, kg}{Quantity\ of\ N\ applied, kg} \dots\dots\dots (1);$$

Where, N-AE= agronomic use efficiency of nitrogen, F=yield of fertilized plot, C=yield of unfertilized or lower fertilized treatment.

2.4 Data Analysis

Collected data for the different traits of the field experiment was analyzed using computer statistical software Genstat-18. Means were compared using Duncan’s Multiple Range Test (DMRT), at P level of 0.01 probability level.

2.5 Economic Analysis

Economic analysis was conducted using partial budget analysis as described by CIMMYT [22]. Fertilizer cost, labor cost (weeding, harvesting and threshing) and adjusted seed yield were used for the economic analysis. Seed yield was reduced by 10% in the analyses to minimize the effect of the small plots managed by researchers compared to the farmer’s management as guided by CIMMYT [22]. All costs and benefits (eq 2-5) were calculated on a hectare basis in the Ethiopian currency, Birr.

The following equations were used:

$$Gross\ benefit = adjusted\ yield * price\ (birr\ kg - 1) \dots\dots\dots (2);$$

$$\text{Netbenefit} = \text{gross benefit} - \text{total variable cost} \dots\dots\dots (3);$$

$$\text{MRR} = \frac{\text{change in NB}}{\text{change in TVC}} \dots\dots\dots (4);$$

Where *MRR* is the marginal rate of return, *NB* is net benefit ha⁻¹ for each treatment, and *TCV* is the total variable costs ha⁻¹ for each treatment.

Dominance is a procedure of selection of profitable treatments from the range tested. The marginal rate of return (MRR) was calculated from the non-dominated treatments (eq 4). MRR denotes the return per unit of investment for the different managements tested in the field. Residual was calculated from the minimum return and net benefits (eq 5). Following the analysis, treatments with the higher Residuals and MRR were recommended to farmers.

$$\text{Residual} = \text{net benefit} - \text{minimum return} \dots\dots\dots (5)$$

Figure 1 Precipitation, minimum, and maximum temperatures of the experimental site over long period of time from New LocClim software (Longitude 36.37oE, Latitude14.15o N, Altitude 600 m); Prec = rainfall (mm), T Max = maximum temperature, T Min = minimum temperature

3 Results

The Analysis of Variance (ANOVA) results shown in Table (2) revealed significant differences among the N doses in terms of 50% flowering (50%F), 90% maturity (90%M), number of branches per plant (NBPP), plant height in cm (PH), number of capsule per plant

(NCPP), thousand seed weight in gram (100SW) and seed yield in kg per ha (SY) under both rain fed and irrigation conditions. The number of branches per plant (NBPP) under irrigation has not shown significant difference and number of seeds per capsule (NSPC) did not show statistical variation in both growing conditions (Table 2).

Table 2 ANOVA (P-values) of the main and interaction effects of N doses and Year on 50% flowering (50%F), 90% maturity (90%M), number of branches per plant (NBPP), plant height in cm (PH), number of capsule per plant (NCPP), number of seeds per capsule (NSPC), thousand seed weight in gram (1000SW) and seed yield in kg per ha (SY). Numbers written in **bold** are significantly different; values>0.05= not significant at $p < 0.05$, values between 0.002-0.05 = significant at $p < 0.05$, values<0.001=highly significant at $p < 0.05$

Sources of Variation		50%F	90% M	NBPP	PH	NCPP	NSPP	1000SW	SY
Rain fed	N rate	0.045	0.050	0.001	0.001	0.001	0.789	0.044	0.001
	Year	0.78	0.999	0.714	0.001	0.026	0.001	0.001	0.001
	N rate*Year	0.999	0.999	0.856	0.101	0.112	0.965	0.429	0.248
Irrigation	N rate	0.024	0.008	0.491	0.001	0.001	0.502	0.001	0.001
	Year	0.001	0.001	0.001	0.098	0.020	0.001	0.001	0.001
	N rate*Year	0.955	0.999	0.471	0.179	0.410	0.969	0.089	0.001

3.1 Physical and Chemical Properties of the Soil

Analysis of soil revealed that the total content of N, P and OC in the soil were very low below the critical levels (0.08%, 7.19 ppm and 1.01%, respectively). The soil pH was high (7.75) (Table 1).

3.2 Weather Conditions

Long term monthly average temperature and rain fall of the experimental area was 29°C and 500 mm, respectively (Figure 1). There were no precipitations at all in the irrigated season and the minimum temperature was lower in the irrigated season compared to the rain fed season, while the maximum temperature was higher in the irrigated season (Figure 1).

3.3 Effect of N fertilizer on sesame phenological traits

N fertilizer has showed statistical variation on the phenological traits of sesame (Table 2). Lower number of days to flowering (42 days) was recorded on the lower N doses (18 to 41 kg N ha⁻¹) where the higher (46 days) was on the maximum N rate (156 kg N ha⁻¹) (Figure 2). The number of days to 90% maturity has varied with N doses under the rain fed condition. Maximum number

of days (84 days) was recorded on lower (18 to 52.5 kg N ha⁻¹) and higher (156 kg N ha⁻¹) N doses, where lower number of days (76-80 days) to 90% maturity recorded from N doses (64 to 121.5 kg N ha⁻¹). Under the irrigation condition; minimum number of days to 50% flowering (35 days) was scored on the lower N rate (18 kg N ha⁻¹), where higher number of days to 50% flowering (38 days) was recorded on the maximum N application rate (156 kg N ha⁻¹). However, days to 90% maturity has not varied with N application rates under the irrigation condition (Figure 2).

Figure 2 Effect of different levels of N fertilizer on the phenological traits of sesame under rain fed and irrigation conditions (D 50% F-I= days to 50% flowering under irrigation, D 50% F-R=days to 50% flowering under rain fed, D 90% M-I=days to 90% maturity under irrigation and D 90% M-R=days to 90% maturity under rain fed conditions).

3.4 Effect of N fertilizer on growth parameters of sesame

Number of branches and plant height showed significant variation among the N doses tested under rain fed and plant height under irrigation condition (Table 2). Maximum number of branches (~3 branches) was recorded on the higher N application rates (64-156 kg N ha⁻¹), while the lower N doses (18-52.5 kg N ha⁻¹) scored lower branch numbers under rain fed condition (Table 3). Regarding the plant stature under the rain fed condition, all the higher N application rates (64-156 kg N ha⁻¹) have scored statistically similar taller plants (141-150 cm) and shorter plants (120-129 cm) were from the lower N doses (18-52.5 kg N ha⁻¹) (Table 3). The shorter plants (79-87 cm) were recorded from the lower N application rates (18-41 kg N ha⁻¹) under

irrigation, where the higher N doses (64-156 kg N ha⁻¹) have recorded statistically similar taller plants (123-138 cm) (Table 4).

3.5 Effect of N fertilizers on sesame yield and yield components

The ANOVA showed that there was a significant variation among the treatments on number of capsules and seed yield (Table 2). Maximum numbers of capsules (~62) were recorded on the 64 and 75.5 kg N ha⁻¹ applied plots, while 18 and 29.5 kg N ha⁻¹ scored the lower capsules. Lower seed yield (712 kg ha⁻¹) was recorded from the lowest N rate (18 kg N ha⁻¹), where the higher sesame seed yield (914-1092 kg ha⁻¹) was harvested from the N fertilizers 52.5-121.5 kg N ha⁻¹ (Table 3).

Table 3 Combined mean comparison of the different *N doses* on sesame seed yield and yield components under rain fed condition (number of branches per plant (NBPP), plant height in cm (PH), number of capsule per plant (NCP) and seed yield in kg per ha (SY))

N doses (kg ha ⁻¹)	NBPP	PH (cm)	NCP	SY(kg ha ⁻¹)
18	2.0 ^{de}	120.9 ^c	30.9 ^g	712 ^d
29.5	1.8 ^e	126.2 ^c	35.0 ^{eg}	855 ^{bcd}
41	2.5 ^{b-e}	125.1 ^c	44.7 ^{def}	934 ^{abc}
52.5	2.3 ^{cde}	129.3 ^{bc}	46.0 ^{cd}	1018 ^{ab}
64	2.6^{cde}	143.8 ^{ab}	61.9 ^a	1087^a
75.5	3.0^{abc}	144.3 ^{ab}	61.5 ^a	1092^a
87	2.6 ^{b-e}	142.7 ^{ab}	58.0 ^{ab}	1080 ^a
98.5	3.2 ^{ab}	141.6 ^{ab}	58.7 ^{ab}	1042 ^{ab}
110	2.7 ^{bcd}	146.5 ^a	50.7 ^{bcd}	1062 ^a
121.5	3.8 ^a	146.6 ^a	56.0 ^{abc}	914 ^{a-d}
133	3.0 ^{abc}	152.7 ^a	46.2 ^{cd}	844 ^{bcd}
144.5	3.1 ^{abc}	156.4 ^a	44.8 ^{de}	853 ^{bcd}
156	3.0 ^{abc}	150.2 ^a	44.8 ^{de}	811 ^{cd}
CV (%)	33.4	10.8	20.6	23
LSD (0.05)	0.85	14.27	9.50	204.3

Numbers followed with similar letters have not significant difference.

Regarding the seed yield across years; minimum seed yield was recorded from the higher and lower N doses (18, 144.5 and 156 kg N ha⁻¹) and the maximum was from 75.5 kg N ha⁻¹ in 2016 production year (Figure 3). In the second year (2017), 87.5 kg N ha⁻¹ followed by 64 kg N ha⁻¹

has recorded the maximum seed yield, whereas 18 kg N ha⁻¹ scored the lowest seed yield. Higher seed yield was also recorded from 75.5 kg N ha⁻¹ and the lower seed yield was harvested under the lowest N application rate (18 kg N ha⁻¹) (Figure 3).

Figure 3 Seed yield responses of the N doses under rain fed conditions across years

The ANOVA showed that there was a significant variation among the N doses on number of capsules, thousand seed weight and seed yield (Table 2). Heavier seed weights (3.6-3.9 g) were recorded on 64, 75.5, 87 and 98.5 kg N ha⁻¹, while the lighter seeds were recorded on the lower N application rates (Table 4). Maximum numbers of capsules (~63) were recorded on the 64 and 75.5 kg N ha⁻¹ applied plots, while 18 and 29.5 kg N ha⁻¹ scored the lower (33) capsules. The higher seed yield was harvested on the 64 and 75.5 kg N ha⁻¹, where the lower seed yield was on the 18 kg N ha⁻¹ (Table 4).

Table 4 Combined mean comparison of the different *N doses* on sesame yield and yield components under irrigation condition (plant height in cm (PH), number of capsule per plant (NCPP), thousand seed weight in gram (100SW) and seed yield kg per ha (SY))

N doses (kg ha ⁻¹)	SY (kg ha ⁻¹)	1000SW (g)	NCPP	PH (cm)
18	437 ^e	2.9 ^c	32.9 ^c	78.8 ^c
29.5	494 ^{de}	2.8 ^c	32.6 ^c	80.5 ^c
41	618 ^{bc}	3.2 ^{bc}	47.6 ^b	87.1 ^{bc}
52.5	625 ^{bc}	3.2 ^{bc}	51.9 ^b	99.6 ^b
64	827 ^a	3.9 ^a	62.7 ^a	125.7 ^a

75.5	894 ^a	3.7 ^{ab}	63.9 ^a	126.5 ^a
87	672 ^{bc}	3.6 ^{ab}	48.9 ^b	123.8 ^a
98.5	707 ^{bc}	3.7 ^{ab}	51.1 ^b	124.2 ^a
110	598 ^c	3.2 ^c	49.1 ^b	125.3 ^a
121.5	647 ^{bc}	3.6 ^{ab}	51.1 ^b	123.6 ^a
133	619 ^{bc}	3.2 ^{bc}	49.7 ^b	127.3 ^a
144.5	606 ^c	3.2 ^{bc}	48.4 ^b	132.1 ^a
156	572 ^{cd}	3.6 ^{ab}	46.9 ^b	137.7 ^a
CV (%)	16.5	19.4	16.1	14.17
LSD (0.05)	99.82	0.62	7.41	16.31

The seed yield responses in each of the irrigation seasons was presented in figure (4). Higher seed yield was harvested from 41-64 kg N ha⁻¹ and the lower was from 18 kg N ha⁻¹ during the first year. Maximum seed yield was recorded from 64 and 75.5 kg N ha⁻¹ and the lower was from 18 and 29.5 kg N ha⁻¹ in both 2017 and 2018 production years (Figure 4).

Figure 4 Seed yield responses of the *N* doses under irrigation conditions across years

Agronomic efficiency of N fertilizer (N-AE) varied significantly ($P = 0.01$) with an interaction between year and treatment (Figure 5). In the rain fed condition, the higher AE (5.9) was calculated from 64 kg N ha⁻¹ and the lower (0.6) was from the higher N application rate (156 kg N ha⁻¹). In the irrigation, the maximum AE (6.1) was recorded from 64 and 75.5 kg N ha⁻¹, while the lower (0.9) was on the higher N dose (Figure 5).

Figure 5 Agronomic Nitrogen Use Efficiency of sesame under rain fed and irrigation conditions

3.6 Results for economic analysis

Results of the N doses under rain fed condition indicated that 64 kg N ha⁻¹ had the higher net profit (40320 Birr ha⁻¹), about 5168 Birr ha⁻¹ increment was achieved in comparison to the 41 kg N ha⁻¹ (Table 5). The 64 kg N ha⁻¹ has a corresponding marginal rate of return (616.3%) and it was supported by the residuals, which was ranked as first compared to the other treatments (Table 6). In the irrigation condition; the 75.5 kg N ha⁻¹ had higher net profit (32579 Birr ha⁻¹), it has achieved about 9683 Birr ha⁻¹ increment compared to the blanket recommendation (41kg N ha⁻¹) (Table 5). In addition, the 75.5 kg N ha⁻¹ has higher corresponding marginal rate of return (84.6%) and also maximum residuals, which was ranked number one (Table 6).

Table 5 Partial budget analysis for the different *N doses* under rain fed (R) and irrigation (I) conditions.

N doses (kg ha ⁻¹)	Cost benefit data											
	A		B		C		D		E		F	
	Adj. Yield kg ha ⁻¹		Price kg ⁻¹		Total revenue Birr ha ⁻¹ (A*B)		Total Variable cost Birr ha ⁻¹		Net profit Birr ha ⁻¹ (C-D)		Dominance (D)	
	R	I	R	I	R	I	R	I	R	I	R	I
18	640.4	393	43	43	27539	16900	0	0	27539	16900		
29.5	769.8	444	43	43	33100	19106	580	580	32520	18526		
41	841	556	43	43	36157	23901	1005	1005	35152	22896		
52.5	916	563	43	43	39389	24195	1380	1380	38009	22815		D
64	978	744	43	43	42075	32009	1755	1755	40320	30254		
75.5	982	805	43	43	42245	34609	2030	2030	40215	32579	D	
87	972	605	43	43	41781	25999	2505	2505	39276	23494	D	D

98.5	937	636	43	43	40310	27357	2880	2880	37430	24477	D	D
110	955	538	43	43	41080	23150	3255	3255	37825	19895	D	D
121.5	823	583	43	43	35380	25054	3630	3630	31750	21424	D	D
133	760	557	43	43	32678	23955	4005	4005	28673	19950	D	D
144.5	767	545	43	43	32995	23448	4380	4380	28616	19068	D	D
156	730	515	43	43	31389	22144	4755	4755	26635	17389	D	D

Table 6 Marginal rate of return and residual analysis for the different *N doses* under rain fed (R) and irrigation (I) conditions.

<i>N doses</i> (kg ha ⁻¹)	G		H		I		J		K		L	
	Marginal cost		Marginal		MRR (H/G)%		Minimum return		Residual (E-J)		Residual	
	Birr ha ⁻¹		benefit Birr ⁻¹				(100%*TCV)				ranking	
	R	I	R	I	R	I	R	I	R	I	R	I
18	0	0	0	0	--	--	0	0	27539	16900	5	5
29.5	580	580	4981	1626	858.8	28.0	425	580	32250	17946	4	4
41	425	425	2632	4370	619.4	102.8	850	1005	34457	21891	3	3
52.5	375	--	2856	--	761.7		1225	--	36939	--	2	--
64	375	375	2311	7439	616.2	198.4	1600	1755	38875	28499	1	2
75.5		275	--	2326	--	84.6	--	2030	--	30549	--	1

4 Discussion

Days to 50% flowering showed an increment as N dose increased (Figure 2). This result might be due to the nitrogen availability in the vegetative growth that might lead the plant to vigorous growth than to flower initiation. In addition, days to 90% maturity somewhat reduced as N rate increased up to 133 kg N ha⁻¹ in the rain fed condition (Figure 2). [Haruna \[23\]](#) noted that unfertilized plot was flowering 14% earlier than the 100 kg N/ha treated plot in moisture deficit areas. Similar results were reported that higher (69 kg N ha⁻¹) nitrogen application has delayed flowering compared to the unfertilized ones in the drought prone parts of north Ethiopia [12]. On the other side, an experiment carried out in higher rainfall areas witnessed that emergence date, flowering date (52 days) and maturity date (89) were not affected by N application rates [5]. It can be concluded that, in the drought prone areas and/or in higher temperature areas, unfertilized sesame may flower earlier than the fertilized one. About 6-8 days difference was observed on 50% flowering between the rain fed and irrigated sesame, which the later one was flowered earlier. This might be because of the higher temperature in irrigation season compared to the rain fed season or months (Figure 1). Branch numbers and plant heights were higher in the higher N

applications and this is in line with the reports of [11] that greater number of branches and taller plants were found in the higher N dose applications (92 kg N ha^{-1}), where untreated plots produced lower values for all the growth characters measured. Moreover, maximum values for agronomic traits of sesame was obtained from application of 92 kg N ha^{-1} [24]. Similarly, plant height was significantly increased by N rate (60 kg N ha^{-1}) as per the report by Haruna [23]. Therefore, it can be concluded that in potential environments, application of higher dose of urea can increase the growth parameters of sesame.

The field experiment conducted in HuARC witnessed that application of 64 kg N ha^{-1} produced 27% capsule number and 15% seed yield increments compared to the previously recommended N rate (41 kg N ha^{-1}) by Mizan *et al* [12] under rain fed (Table 3). In the irrigation, 64 and $75.5 \text{ kg N ha}^{-1}$ have 25% and 30% seed yield increments, respectively, over the blanket recommendation (41 kg N ha^{-1}) (Table 4). This result aligns with studies conducted on application rates that 50 kg N ha^{-1} produced significantly higher number of capsules (83.8) and seed yield (888 kg ha^{-1}) compared with the lower rate and untreated plots [25]. Higher seed yield was obtained when 75 kg N ha^{-1} dose was applied, where the lower and higher doses (0 and 133 kg N ha^{-1}) recorded lower seed yield [26]. Similarly, application of 80 kg N ha^{-1} produced 752 kg ha^{-1} seed yield [27]. Furthermore, in the higher rainfall areas with lithosols higher seed yield was recorded when 75 kg N ha^{-1} was applied [28]. Haghighatnia *et al* [26] reported that higher yield was obtained from 50 kg N ha^{-1} compared to 160 kg N ha^{-1} and Blal *et al* [27] reported also higher seed yield of sesame was harvested when 92 kg N ha^{-1} was applied rather than 160 kg N ha^{-1} application. Field experiments conducted under irrigation condition in Egypt reported that seed yield were increased significantly when 92 kg N ha^{-1} applied rather than 156 kg N ha^{-1} [27]. Zenawi and Mizan [13] reviewed that application of nitrogen fertilizer for sesame could differ based on growing environments (considering the edaphic and climate conditions) 46 up to 100 kg N ha^{-1} . Agronomic efficiency of nitrogen fertilizer (N-AE) indicated that the 64 kg N ha^{-1} in comparison to 41 kg N ha^{-1} has about 0.5 and 1.7 kg additional amount of economic seed yield per a kg of N applied under rain fed and irrigation, respectively, and $75.5 \text{ kg N ha}^{-1}$ has also scored 1.6 kg of seed yield per applied kg of N under irrigation (Figure 5). N-AE of the higher N doses was below 1 kg kg^{-1} , this might be caused by the vigorous and leafy growth during the vegetative stage that prolonged flower initiation. Besides the agronomic efficiency results of the partial budget analysis also clearly confirmed that the additional capital invested in 64 kg N ha^{-1} under rain fed condition scored greater net profit and MRR. Besides both 64 kg N ha^{-1} and 75.5

kg N ha⁻¹ had the higher net profit and MRR than all the other treatments under the irrigation condition.

5 Conclusion

Higher no. of days to 50% flowering was on the 156 kg N ha⁻¹ and the lower days on 18 N ha⁻¹. The higher N doses have maximum number of branches and statures, while the lower N doses 18-52.5 have not. The medium ranges of N applications (64-121.5 kg N ha⁻¹) produced higher number of capsules and seed yield, where the lower and higher doses of N scored low values under rain fed condition. Only the 64 and 75.5 kg N ha⁻¹ gave higher values for agronomic traits under irrigation condition. Agronomic efficiency of N fertilizer was higher on 64 kg N ha⁻¹ under both growing conditions. The partial budget analysis also revealed that 64 kg N ha⁻¹ and 75.5 kg N ha⁻¹ had the higher net profit, MRR and residual ranking under rain fed and irrigation respectively. Therefore, for the maximum sesame productivity 64 kg N ha⁻¹ for rain fed and 64 to 75.5 kg N ha⁻¹ should be recommended for irrigated sesame.

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