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OPTIMAL RATE OF NITROGEN AND INTRA-ROW SPACING FOR ECONOMICAL PRODUCTION OF ONION UNDER IRRIGATED FARMING SYSTEM IN EASTERN AMHARA REGION, ETHIOPIA

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ABSTRACT

Onion is one of the most important cash crops produced by smallholder farmers mainly during the irrigation season. However, the productivity of onion in Amhara Region is very low which is mainly associated with improper agronomic practices. This research was therefore conducted to increase the productivity of onion by identifying the optimum rate of nitrogen and intra-row spacing for economical production of the crop in Alawuha Small-Scale Irrigation Scheme. Four rates of nitrogen (0, 41, 82, 123 kg ha-1) and three intra-row spacing (6, 8, 10 cm) in factorial combination were laid out in Randomized Complete Block Design with three replications. Results indicated that nitrogen and intra-row spacing significantly influenced most of the growth and phenological parameters of onion where application of 123 kg ha-1 nitrogen increased leaf number by 67.3% and prolonged days to maturity of onion by about 7 days compared to the respective control plants. Similarly, nitrogen rate and intra-row spacing significantly affected bulb yield of onion where the highest marketable bulb yield (37.48 t ha-1) was recorded by application of 123 kg ha-1 on plants spaced at 6 cm intra-row spacing which was statistically similar with those yield (35.07 t ha-1) recorded with the combination of 82 kg ha -1 nitrogen and 6 cm intra-row spacing. Application of 123 kg ha-1 nitrogen on plants spaced at 6 cm intra-row spacing is recommended for production of onion in Alawuha Small-Scale Irrigation Scheme as it recorded the highest net benefit (Eth-Birr 429,569) with relatively high marginal rate of return.

Contribution/Originality: This study is one of very few studies which have investigated the influence of nitrogen rate and intra-row spacing on the bulb yield of onion in Amhara Region. Therefore, the findings of the present study will contribute to the improvement of production and productivity of onion in Eastern Amhara, Ethiopia.

1. INTRODUCTION

Onion (*Allium cepa* L.) belongs to the genus *Allium* of the family *Alliaceae* [1]. It was probably originated in central Asia between Turkmenistan and Afghanistan where some of its relatives are still growing as wild plants [2]. The crop was introduced to South-East Asia, Mediterranean areas and Roman Empire [3].

Onions contribute significant nutritional value to the human diet and have medicinal properties. They are primarily consumed for their unique flavor to enhance the flavors of foods [4]. In Ethiopia, the onion is one of the most important vegetables produced by smallholder farmers mainly as a source of cash income and for flavoring the local stew '*wot*' [5]. In the country, the crop is believed to be more intensively consumed than any other vegetable crops [6]. Moreover, the onion contributes to the commercialization of the rural economy and creates jobs opportunities for young people in the country [7].

Onion is produced both under irrigation and rain fed conditions in Ethiopia as well as in Amhara Region [5] The bulk of onion produced in Amhara Region comes from this region where cultivation is mainly carried out using irrigation [8]. The productivity of onion in the region [9] as well as in Ethiopia is however very low (9.74 t ha^{-1}) compared to the world's average (19.3 t ha^{-1}) as indicated by Central Statical Agency [10] and Food and Agriculture Organization [11]. Land degradation mainly due to the rapidly growing population and lack of soil fertility management and improper agronomic practices, diseases and insect pests and poor extension services are among other the main challenges that lead to low levels of vegetables including onion in Amhara Region as well as in the country [9].

Implementing appropriate agronomic practices including application of fertilizer and proper spacing has an undoubted contribution for crop yield increment including onion where optimum fertilizer rates and plant spacing vary with the type of crops, environmental conditions and soil fertility of the area. Nitrogen is one of the most important nutrients required for growth and development of plants as it is the component of proteins, enzymes, and vitamins in plants and as well as central part of essential photosynthetic molecule and chlorophyll [12]. The requirement of plants for nitrogen is mostly satisfied either from soil and or application of nitrogen fertilizer. In this regard, Minister of Agriculture [13] recommended the application of 92 kg ha^{-1} P_2O_5 and 46 kg ha^{-1} N for production of onion in Ethiopia without considering the soil fertility and the environmental conditions. While nitrogen application is known to increase yield of onions, many researchers on the other hand, found that high levels of nitrogenous fertilizer reduced onion storage life [14] delayed bulb maturity and increased bolting, which are undesirable characteristic of onion [15].

Spacing is an important aspect regarding onion production and quality. Researchers indicated that wider spacing helped the individual plant to utilize more water, nutrients, air and light for their growth and development than those closer spaced plants [16]. Optimization of plant population is therefore important to avoid competition between plants for growth factors as well as to utilize available cropland efficiently without wastage [17]. In this regard, Ethiopian Agricultural Research Organization [18] recommended the spacing of 40 cm x 20 cm x 10 cm between furrows, row and plants, respectively, for the production of onion in Ethiopia without considering the status of soil fertility and environmental conditions of the growing areas. However, onion bulbs produced using this intra-row spacing are mostly bigger in size (>160 g) which are not preferred by consumers for home consumption [19]. According to Tegen, et al. [19] the proportion of medium-sized bulbs which are preferred by consumers was low at this intra-row spacing. In this regard, Dessalegn and Aklilu [5] reported that availability of full information packages including optimum rate of nitrogen and intra-row spacing for each growing areas is paramount important to increase production and productivity of onion. In view of these, the present study was initiated to determine the optimum fertilizer rate and intra-row spacing for economical production of onion in Eastern Amhara Region.

2. MATERIALS AND METHODS

2.1. Description of the Study Area

A field study was conducted during the 2017/2018 from October to January under irrigation in Alawuha Model Nursery Site at Doro Giber Kebele of Gubalafto district, Northeastern Ethiopia. Experimental site is located at 11°53'N latitude and 38°51'E longitude Figure 1 with the altitude of 1510 meter above sea level. Alawuha is characterized by bimodal and erratic rainfall that varies widely from 800-1050 mm in year where a short rainy season is occurred between February and April, and a long rainy season is occurred between June and September. Gubalafto district has vast plain land suitable for large scale irrigated agriculture and livestock production where the soil is mostly clay loam in texture. The mean monthly minimum and maximum temperatures are 20°C and 22.5°C, respectively.

2.2. Experimental Treatments, Design and Procedures

The treatments consisted of four levels of nitrogen (0, 41, 82, and 123 kg ha^{-1}) and three intra- row spacing (6, 8, and 10 cm) which were factorial combined in Randomized Complete Block Design (RCBD) with three replications. The size of each plot was 3 m x 1.5 m which accommodated ten single rows with 250, 188, and 150 plants per plot for the intra-row spacing of 6, 8 and10 cm, respectively. The distance between plots and blocks were 1 m and 1.5 m, respectively.

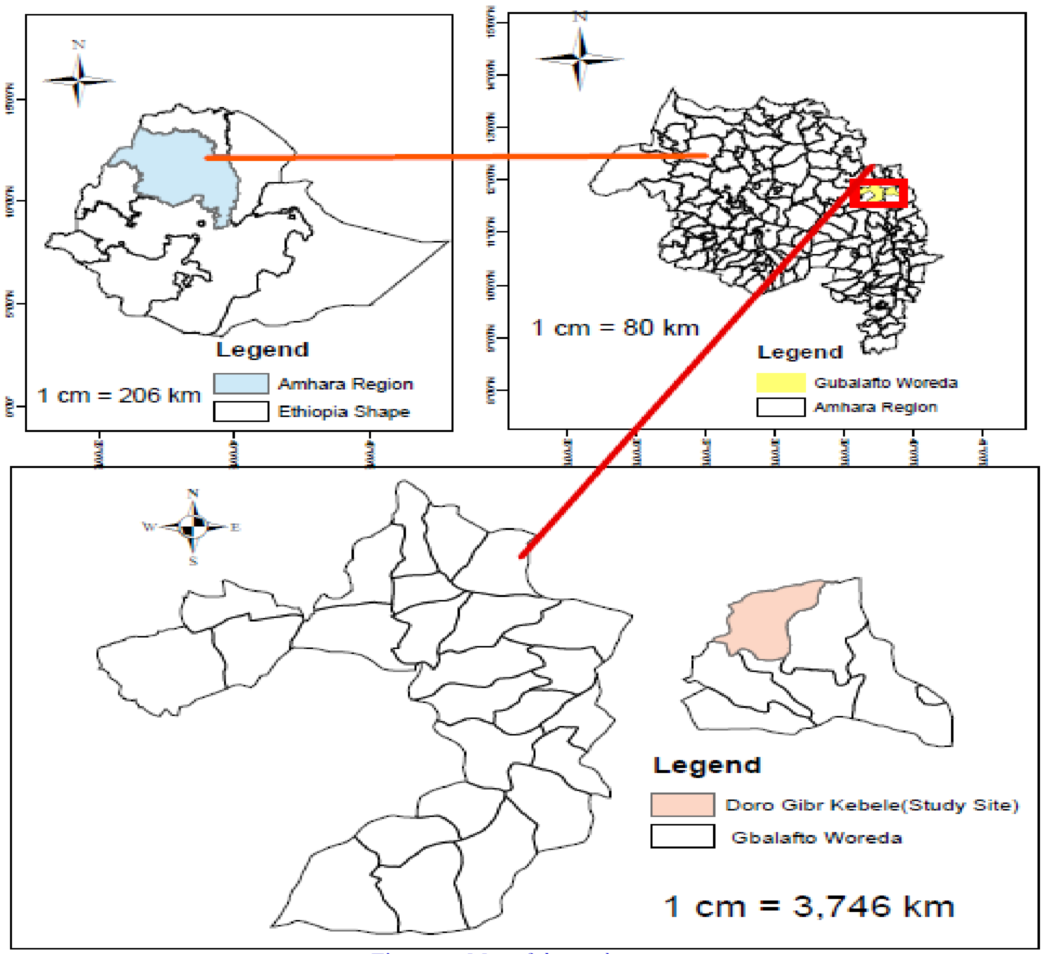

Figure-1. Map of the study area.

Source:: Gubalafto District Agricultural Office (2017)

Seedlings of Bombay Red variety of onion were grown on well prepared nursery beds using the recommended management practices. The variety is well adapted and widely cultivated in the study area. Before seedling transplanting, experimental field was ploughed, pulverized, and leveled and a total of 36 experimental plots were prepared where the size of each plot was 3 m x 1.5 m and accommodated ten single rows with 250, 188, and 150 plants per plot for the intra-row spacing of 6, 8 and10 cm, respectively. The distance between plots and blocks were 1 m and 1.5 m, respectively.

After 45 days healthy, vigorous and uniform-sized seedlings were transplanted on the experimental field with double row planting system at the spacing of 40 x 20 cm between irrigation furrows (double row) and rows of plants, respectively, as well as 6, 8 and 10 cm between plants in the rows based on the treatments.

Triple super phosphate was applied as sources of phosphorous at the rates of 92 kg ha^{-1} P_2O_5 for all plots uniformly during transplanting as recommended by Minister of Agriculture [13]. Based on the treatments, about 50% of predetermined nitrogen rate was applied as side dressing at 20 days after transplanting, while the remaining half of nitrogen was applied four weeks after transplanting [20].

2.3. Soil Sampling

Soil samples were taken from five representative points of the experimental site at the depth of 0-30 cm and composite soil sample was prepared. The composite sample was sub-divided into working samples, air dried, lightly crushed with wooden pestle and screened to determine the physicochemical properties of the soil. Soil analysis was carried out at Sirinka Agricultural Research Center Soil laboratory based on the standard methods. The total nitrogen, available phosphorus and organic matter content, soil pH, organic carbon, cation exchange capacity (CEC), Electric Conductivity (EC) and soil texture were analyzed from the composite soil sample.

3. DATA COLLECTION AND ANALYSIS

3.1. Growth Parameters

Plant height (cm): Plant height was measured using ruler from the soil surface to the tip of longest leaf of ten randomly selected plants grown in the net plot area at physiological maturity and the mean values were computed for further analysis.

Number of leaves: The total number of leaves was counted from ten randomly selected plants grown in the net plot area during physiological maturity and mean values per plant were computed and used for further analysis.

Days to maturity (Days): It was determined by counting the number of days elapsed from date of transplanting to the date when 75% of the plants in each plot showed yellowing of leaves and bent at the neck..

3.2. Yield Components

Bulb weight (g): The fresh weights of ten randomly selected bulbs harvested from the net plot area were measured using sensitive balance and the mean values used for further analysis.

Marketable yield (t/ha): Onion bulbs harvested from the net plot area that were free of mechanical, disease and insect pest damages, physiological disorders, discolorations and that ranges from 20 g to 160 g in weight were considered as marketable as described by Lemma and Shimeles Dessalegn and Aklilu [5] and Morsy, et al. [21]. The weight of such bulbs was weighed using sensitive balance and expressed in ton per hectare.

Unmarketable yield (t/ha): Bulbs which were under as well as over sized (<20g and >160g), misshaped, decayed, discolored, diseased and physiologically disordered were considered as unmarketable as described by Dessalegn and Aklilu [5]. The weights of such bulbs obtained from the net plot area were measured using sensitive balance and expressed in ton per hectare.

Total bulb yield (t/ha): The total bulb yield was obtained as summation of marketable and unmarketable yields.

The collected data were subjected to analysis of variance (ANOVA) as described by Gomez and Gomez [22] using Statistical Analysis Software (SAS, 2004, version 9.0). Treatment mean separation was done using Fisher's Least Significant Differences (LSD) test at 1% or 5% levels of significance depending on the results of ANOVA.

3.3. Economic Analysis

To evaluate the economic feasibility of the treatments economic analysis in the form of partial budget analysis and marginal rate of return was done using the procedures described by CIMMYT [23]. The cost of urea, seed and the labor required for placement of fertilizer and transplanting of seedling was used as variable cost where the market prices of fertilizer, seed and cost of labor as well as farm gate price of marketable onion were taken from market assessment during the experimental period.

4. RESULTS AND DISCUSSION

4.1. Selected Soil Physico-chemical Properties of the Study Area

The results of laboratory analysis of the experimental soil are presented below Table 1. Accordingly, the soil of the experimental site was clay loam in texture with slightly acidic pH [24]. The soil had medium total nitrogen and high phosphorous content as indicated by Tadesse [25] and Hazelton and Murphy [26]. According to Donald, et al. [27] the organic matter content of the experimental soil was moderate while Cation exchange capacity and electrical conductivity were high and low, respectively [26]. Based on the laboratory results, the experimental soil was generally suitable for onion production.

Table-1. Physico-chemical properties of the experimental soil.

Soil properties	Unit	Value	Rating	Sources
Total N	%	0.16	Medium	Tadesse [25]
Total available P	ppm	29.65	High	Hazelton and Murphy [26]
pH	-	6.6	Slightly acidic	Savva and Frenken [24]
Cation exchange capacity	Cmol(+)/kg	33.13	High	Hazelton and Murphy [26]
Electrical conductivity	dS /m	0.18	Low	Hazelton and Murphy [26]
Organic carbon	%	1`.32	Medium	Tadesse [25]
Organic matter	%	2.28	Moderate	Donald, et al. [27]
Particle size distribution				
Sand	%	46.66		
Silt	%	26.66		
Clay	%	26.66		
Textural class		Clay-loam		

Source: Sirinka Agricultural Research Center Soil Laboratory (2017).

4.2. Growth Parameters of Onion

4.2.1. Plant Height

The analysis of variance revealed that the interaction effect of nitrogen and intra-row spacing significantly ($P \leq 0.05$) influenced the heights of onion plants. The tallest onion plant (58.08 cm) was recorded with the combination of 123 kg ha^{-1} N and 10 cm intra-row spacing which was by about 59% higher than those plants planted at closer intra-row spacing without nitrogen Table 2. The increased plant height at the combination of higher rate of N and wider spacing might be due to the fact that nitrogen is the building blocks of amino acids and proteins that improves the growth and development of plants including onion. Moreover, it could be attributed to less competition of the plants for nutrients and other growth factor in widest intra-row spacing. The results of the present study are consistent with the findings of Al-Fraihat [28] and Abdissa, et al. [29] who reported that increasing rates of nitrogen up to certain level increased plant heights of onion which is associated with its vegetative growth promoting effect. Similar, Khan, et al. [30] observed an increase of onion plant heights with increased nitrogen rates at wider intra-row spacing.

Table-2. Interaction effect of nitrogen and intra-row spacing on height of onion plants grown in Doro Gibir *Kebele* at Alawuha Small-Scale Irrigation.

Nitrogen rate (kg ha^{-1})	Intra-row spacing (cm)		
	6	8	10
0	36.55g	41.21f	45.30de
41	42.96ef	44.44e	45.76cde
82	48.98cd	52.88b	56.25a
123	48.66c	56.66a	58.08a
P-value	*		
CV (%)	3.58		
SE±	1.72		

P-value = Probability value; CV = Coefficient of variance; SE = Standard error; * = significant; Means followed by the same letter (s) are not significantly different at P = 0.05.

4.2.2. Leaf Number per Plant

The analysis of variance revealed that number of leaves per plant was very highly significantly ($P\leq 0.001$) influenced by the main effects of nitrogen and intra-row spacing. However, the interaction of these factors had not influenced leaf number per plant. Increasing the nitrogen rate from 0 to 123 kg ha^{-1} significantly increased the leaf number by about 67.3% while increasing the intra-row spacing from 6 to 10 cm increased the leaf number of onions by 24% as indicated in Table 3.

The results of the study indicate that nitrogen plays a pivotal role in leaf production and thus in promotion of vegetative growth of onion plants. The increment of leaf numbers with increased nitrogen rates at wider intra-row spacing observed in the present study is clearly associated with less competition of plants for nitrogen where more auxiliary branches have been produced at wider intra-row spacing compared to closely spaced plants. In agreement with the results of the present study, Jilani, et al. [31] observed maximum number of onion leaves at 25 cm intra-row spacing followed by 20 and 10 cm intra-row spacing. Similarly, Akoun [32] reported more onion leaves were produced at lower plant density than at higher plant population.

4.2.3. Days to Maturity

The analysis of variance showed that days to maturity was very highly significantly ($P\leq 0.001$) influenced by the main effects of nitrogen and intra-row spacing. Nevertheless, the interaction effect of intra-row spacing and nitrogen levels did not showed significant variation on this parameter. Application of highest rate of nitrogen (123 kg ha^{-1}) prolonged days of onion maturity by about seven days as compared to controlled plant. Similarly, the highest intra-row spacing (10 cm) prolonged onion maturity Table 3. The results of this study clearly showed that excess nitrogen delayed onion maturity by extending the vegetative growth period of plants which is in agreement with the findings of various researchers. Morsy, et al. [21]. Similarly, Abdissa, et al. [29] reported that application of nitrogen fertilizer significantly extended days of physiological maturity of onion by about 6 days over the unfertilized plants.

The prolonged maturity days of onion at wider intra-row spacing is obviously associated with less competition of plants for growth factors including nitrogen. Less competition of plants for growth factors may prolong vegetative growth period and thus delayed bulb maturity of onion. On the other hand, the reduced intra-row spacing between plants may exert competition for nitrogen that forced the plants to mature earlier which in line with the findings of Brewster [33]. According to the authors, decreasing intra-row spacing between plants may reduce vegetative growth and reduce duration of onion bulb maturity.

Table-3. Main effects of nitrogen and intra-row spacing on leaf number and maturity of onion plants grown in Doro Gibir *Kebele* at Alawuha Small-Scale Irrigation.

Treatment	Growth parameters	
Nitrogen fertilizer rate (kg ha^{-1})	**Leaf number plant^{-1}**	**Day to maturity (days)**
0	7.77d	111.22d
41	9.92c	113.11c
82	11.48b	116.00b
123	13.00a	118.00a
Significance level	***	***
Intra-row spacing (cm)		
6	9.57c	113.58c
8	10.25b	114.58b
10	11.82a	115.58a
P-value	***	***
CV (%)	7.56	0.23
SE±	0.80	0.26

CV = Coefficient of variance; SE = standard error; P-value = probability; *** = very highly significant; Means within a column followed by the same letter(s) are not significantly different at P≤0.001.

4.3. Yields of Onion

4.3.1. Bulb Weight

The analysis of variance showed that the main effects of nitrogen and intra-row spacing very highly significantly ($P < 0.001$) influenced the bulb weight of onion. However, the interaction effect of nitrogen and intra-row spacing did not influence the average bulb weight significantly. Increasing the application rates of nitrogen from 0 to 82 kg ha^{-1}has increased the bulb weight by 101.9%. However, further increasing the nitrogen rates beyond 82 kg ha^{-1} N did not increased the bulb weights of onion Table 4. Similarly, widening the intra-row spacing from 6 to 10 cm increased the bulb weight by about 13.7%.

Application of nitrogen generally enhances the production of assimilate and dry matter accumulation in plants including onion which is in line with the results of the present study. Similar results were also recorded by Soleymani and Shahrajabian [34] and Aliyu, et al. [15] who reported an increase of onion bulb weight with increased nitrogen rate.

The increased bulb weight at the widest intra-row spacing recorded in the present study is possibly due to less competition of plants for growth factors such as nutrients, light and water. These results are similar with Khan, et al. [35] who reported that wider spacing accommodated less number of onion plants and helps them to absorb adequate nutrients, moisture and light for increased bulb weight.

Table-4. Main effects of nitrogen and intra-row spacing on onion bulb weight in Doro Gibr *Kebele* at Alawuha Small-Scale Irrigation.

Treatment	Bulb weight (g)
Nitrogen fertilizer rate (kg N ha^{-1})	
0	42.48^{c}
41	57.94^{b}
82	85.76^{a}
123	86.62^{a}
P-value	***
Intra-row spacing (cm)	
6	64.28^{b}
8	67.24^{b}
10	73.08^{a}
P-value	***
CV (%)	5.94
SE±	4.05

CV = Coefficient of variance; SE = standard error; P-value = probability; *** = very highly significant; Means within a column followed by the same letter(s) are not significantly different at P≤0.001.

4.3.2. Marketable Bulb Yield

The analysis of variance revealed that the main and interaction effects of nitrogen and intra-row spacing very highly significantly influenced the marketable yield of onion. The maximum marketable bulb yield (37.48 t ha^{-1}) of onion was recorded by application of 123 kg ha^{-1} nitrogen on narrow spaced plants (6 cm) which increased the marketable yield by about 126.9% compared to the yield obtained from treatment combination of 10 cm intra-row without nitrogen Table 5.

Generally, marketable bulb yield of onion was increased when the increased nitrogen rates were combined with increasing plant population. This might be due to the fact that higher plant population per unit area coupled with optimum supply of nitrogen results maximum number of bulbs that leads to higher marketable onion yield. These results are consistent with findings of various researchers where maximum bulb yield of onion was recorded in general with treatment combinations of narrow intra-row spacing and optimum nitrogen fertilizer levels Islam, et al. [36]. Soleymani and Shahrajabian [34] also reported higher marketable onion yield by application of high level (120 kg ha^{-1}) of nitrogen. According to Kahsay, et al. [37] the marketable onion yield was decreased from 34.49 to 28.1 t ha^{-1} when the intra-row spacing increased from 5 to 10 cm.

4.3.3. Unmarketable Bulb Yield

The lowest unmarketable onion yield (0.28 t ha^{-1}) was recorded by application of 123 kg ha^{-1} nitrogen to widest spaced (10 cm) plants which was statically similar with the combined effect of 123 kg ha^{-1} nitrogen and 8 cm intra-row spacing. On the other hand, the highest unmarketable yield (1.05 t ha^{-1}) was obtained by the combination of null nitrogen with 6 cm intra-row spacing which increased unmarketable bulb yield by about 275% compared with the treatment combination of 123 kg ha^{-1} N with 10 cm intra-row as indicated in Table 5.

High unmarketable bulb yield of onion observed in the treatment combination of 6 cm intra-row spacing with null nitrogen could be obviously associated with higher plant competition for nitrogen that reduced vegetative growth and assimilate production that in turn resulting production of very small-sized bulbs which are not preferable by the consumers. The findings of the present study are in agreement with those of Seck and Baldeh [38] and Kahsay, et al. [37] where closer intra-row spacing increased unmarketable bulb yields of onion and shallot, respectively. Likewise, Aregay, et al. [39] reported that onion plants without nitrogen fertilizer produced small-sized onion bulbs which were unmarketable.

4.4. Total Bulb Yield

Similar to marketable yield, the highest total bulb of onion (37.97 t ha^{-1}) was recorded by the treatment combination of 123 kg ha^{-1} nitrogen with 6 cm intra-row spacing which increased total bulb yield by about 181% when compared to the treatment combination of null nitrogen with 10 cm intra-row spacing Table 5.

The increased total onion bulb yield by the combination of increased nitrogen level with increased plant density observed in the present study is associated with the supply of enough nitrogen that is necessary to improve the vegetative growth of plants that in turn boost the production of photosynthetic products. The present results are line with Eifediyi, et al. [40] who reported that total bulb yield was higher in narrow spaced plants than in wider spaced plants if enough plant nutrients are available in soil. This might be ascribed to the enhanced number of bulbs per unit area. Aliyu, et al. [15] also found that increase the rate of nitrogen dose up to 100 kg ha^{-1} resulted higher onion bulb yield but further increase of nitrogen to 150 kg ha^{-1} did not significantly increase the yield.

Table-5. Interaction effects of nitrogen and intra-row spacing on bulb yield of onion grown in Doro Gibir *Kebele* at Alawuha Small-Scale Irrigation.

Treatments		Onion yields		
Rate of nitrogen (kg ha^{-1})	Intra-row spacing (cm)	Marketable bulb yield (t ha^{-1})	Unmarketable bulb yield (t ha^{-1})	Total bulb yield (t ha^{-1})
0	6	16.52g	1.05a	17.58g
	8	15.95g	0.64bc	16.59g
	10	12.88h	0.59cd	13.48h
41	6	27.84d	0.72b	28.56d
	8	21.24ef	0.53de	21.76ef
	10	18.96fg	0.42fg	19.38fg
82	6	35.07ab	0.57cde	35.64ab
	8	29.73cd	0.48ef	30.22cd
	10	22.63e	0.35gh	22.98e
123	6	37.48a	0.49ef	37.97a
	8	32.43bc	0.32h	32.76bc
	10	23.69e	0.28h	23.97e
P-value		***	***	***
CV (%)		7.29	9.59	7.18
SE±		1.78	0.05	1.8

CV = Coefficient of variance; SE = standard error; P-value = probability; *** = very highly significant; Means within a column followed by the same letter(s) are not significantly different at P≤0.001.

4.5. Economic Analysis of Onion as Affected by Nitrogen and Intra-Row Spacing

Costs of fertilizer, seed and labor were considered as variable costs as they vary with the treatments. Variable costs were calculated by considering the local prices which were existed during the experimental period. Moreover, gross income obtained from each treatment was calculated using the farm gate price of onion where the marketable yield was down scaled by 10%. Accordingly, application of 123 kg ha^{-1}nitrogen on narrow spaced plants (6 cm) recorded the highest net benefit of onion (Eth-Birr 429,569.0) followed by the treatment combination of 82 kg ha^{-1} nitrogen with 6 cm intra-row spacing Table 6. On the other hand, the lowest net benefit was obtained from plants spaced at 10 cm combined with null nitrogen.

Moreover, marginal rate of return was calculated based on the procedures described by CIMMYT [23]. Accordingly, treatments were arranged in ascending order based on variable costs where treatments which had net benefits less or equal to the previous treatments were eliminated Table 7. Consequently, the treatment 82 kg ha^{-1} nitrogen combined with 6 cm intra-row spacing recorded the highest marginal rate of return followed by the combination of 123 kg ha^{-1} nitrogen with 6 cm intra-row spacing. However, since the marginal rate of return is much higher than 50%, the treatment combination of 123 kg ha^{-1} nitrogen with 6 cm intra-row spacing with the highest net benefit was selected for economical production of onion in the study area.

Table-6. Partial budget analysis of onion as affected by nitrogen and intra-row spacing in Doro Gibir Kebele at Alawuha Small-Scale Irrigation.

Treatment combination	MY (t ha^{-1})	AMY (t ha^{-1})	GI (Eth Birr)	CS (Eth Birr)	CF (Eth Birr)	LCT (Eth Birr)	LCFA (Eth Birr)	TVC (Eth Birr)	NB (Eth Birr)	Rank
6×0	16.52	14.86	193,180	2,664	0	3,500	0	6,164	187,016	11
6×41	27.84	25.06	325,780	2,664	719	3,500	400	7,283	318,497	5
6×82	35.07	31.57	410,410	2,664	1,438	3,500	500	8,102	402,308	2
6×123	37.48	33.73	438,490	2,664	2,157	3,500	600	8,921	429,569	1
8×0	15.5	13.95	181,350	2,000	0	3,000	0	5,000	176,350	12
8×41	21.24	19.12	248,560	2,000	719	3,000	400	6,119	242,441	8
8×82	29.73	26.76	347,880	2,000	1,438	3,000	500	6,938	340,942	4
8×123	32.43	29.19	379,470	2,000	2,157	3,000	600	7,757	371,713	3
10×0	18.06	16.25	211,250	1,600	0	2,500	0	4,100	207,150	10
10×41	18.96	17.06	221,780	1,600	7,19	2,500	400	5,,219	216,561	9
10×82	22.63	20.37	264,810	1,600	1,438	2,500	500	6,038	258,772	7
10×123	23.69	21.32	277,160	1,600	2,157	2,500	600	6,857	270,303	6

MY= Marketable yield, AMY = Adjusted marketable yield, CS =, Cost of seed, CF = Cost of fertilizer, LCT = Labor cost for transplanting, LCFA = Labor cost for fertilizer application, TVC = Total variable cost, NB = Net benefit.

Table-7. Marginal rate of return of onion as affected by nitrogen and intra-row spacing in Doro Gibir *Kebele at* Alawuha Small-Scale Irrigation.

Intra-row spacing x Nitrogen rate	TVC (Birr ha^{-1})	NB (Birr ha^{-1})	DA	MR (%)	Rank
10×0	4100	207150		-	
8×0	5000	176350	dominated		
10×41	5219	216561		841	7
10×82	6038	258772		5153	3
8×41	6119	242441	dominated		
6×0	6164	187016	dominated		
10×123	6857	270303		1407	6
8×82	6938	340942		8708	2
6×41	7283	318497	dominated		
8×123	7757	371713		3757	4
6×82	8102	402308		8868	1
6×123	8921	429569		3328	5

TVC = total variable cost, NB = net benefit, DA = dominance analysis, MRR = marginal rate of return

5. CONCLUSION

The rate of nitrogen and intra-row spacing influenced both growth and yield of onion grown in the study area. While the tested growth parameters of onion including plant height, leaf number and days to maturity were influenced only by the main effects, yield components of onion were also influenced by the interaction effects of nitrogen and intra-row spacing. Accordingly, all the tested growth parameters of onion were increased with increasing rate of nitrogen and widening of intra-row spacing where plants supplied by 123 kg ha^{-1} as well as those planted at 10 cm intra-row spacing recorded were best in all growth parameters. On the other hand, the highest marketable (37.48 t ha^{-1}) and total (37.97 t ha^{-1}) bulb yields of onion with the highest net benefit were obtained by the treatment combination of 123 kg ha^{-1} nitrogen with 6 cm intra-row spacing. Since the combination of 123 kg ha^{-1} nitrogen with and 6 cm intra-row spacing recorded acceptable high marginal rate of return, it can be recommended for economical production of onion at Alawuha Small Scale Irrigation Scheme, Northeastern Amhara Region.

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