Effect of Inter-Row Spacing and Nitrogen Rates on Growth, Yield Components, and Yield of Okra [*Abelmoschus esculentus* (L.) Moench] at Assosa, Western Ethiopia

A Thesis Submitted to the Post Graduate Programs Directorate, School of Plant Science， Haramaya University, In Partial Fulfilment of the Requirements for the Degree of Master Of Science In Agriculture (Agronomy)

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Abstract: *Okra [Abelmoschus esculentus (L.) Moench]* is produced traditionally in Assosa as one of the food and medicinal crops. But its yield is low due to inappropriate plant spacing and fertilizer use. Therefore, this research was conducted to assess the effect of inter-row spacing (IRS) and rates of nitrogen (N) fertilizer on growth, yield components, and yield of the crop at Assosa. The treatments consisted of three inter-row spacing (IRS) (30 cm, 45cm and 60 cm) and five rates of N fertilizer (0, 23, 46, 69, 92 kg N ha^{-1}) in factorial combinations in which the intra-row spacing of 30cm was maintained for all plots. The experiment was laid out in randomized completely block design with three replications. Seeds of farmers' cultivar of okra obtained from the vicinity were used as planting material. The main factors (IRS and N) and the interaction of the two factors had significant ($P<0.05$) effect on the number of branch plant^{-1}, number of tender fruit plant^{-1}, weight of single tender fruit, weight of tender fruit plant^{-1} and marketable tender fruit ha^{-1}. Days to 50% flowering, days to pod setting, period of harvest, number of harvests plant^{-1} and yield of tender fruit ha^{-1} were significantly ($P<0.05$) influenced by IRS and N fertilizer. Plant heights at flowering and at last harvest were affected significantly ($P<0.05$) only by the inter-row spacing. The highest tender fruit yield (30.35 t ha^{-1}) was obtained in response to planting at the inter-row spacing of 60 cm, which was in statistical parity with fruit yield obtained in response to planting at the inter-row spacing of 45 cm. The highest fruit yield (31.12 tha^{-1}) was also attained for plants that received fertilizer at the rate of 92 kg N ha^{-1}, which was in statistical parity with fruit yield obtained in response to the application of 69 kg N ha^{-1}. However, the partial budget analysis results showed that a combined treatment application of inter-row spacing of 60 cm and 69 kg N ha^{-1} had higher marginal rate of return (5833.33%) than combined treatment application of inter-row spacing of 60 cm and 92 kg N ha^{-1} (250%). This indicates that for one Birr extra cost due to treatment application of inter-row spacing of 60 cm and 69 kg N ha^{-1} a farmer could benefit from obtaining 58.33Birr. Therefore, it can be concluded that planting okra at the inter-row spacing of 60 cm and an application of nitrogen fertilizer at the rate of 69 kg ha^{-1} resulted in an optimum fruit yield of the crop in the study area.

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1. Introduction

Okra [*Abelmoschus esculentus* (L.) Moench], also known as Lady's finger is a common vegetable crop grown under tropical and subtropical conditions and native to tropical Africa which is one of the prized vegetables in many countries (Chadha, 2002). Okra is especially valued for its tender delicious fruits and is a good source of essential vitamins (e.g., Vitamin C) and minerals such as calcium, phosphorus, magnesium and iron. It possesses high nutritive value, which is higher than tomatoes, eggplant and most cucurbits except bitter gourds (Berry *et al*., 1999). The dried okra pods are consumed directly and they are also used as flavouring in preparing other food products. Okra is also valuable with regards to anti-carcinogenicity, human immunity promotion, ageing prevention and health-care (Lee *et al*., 2001; AVRDC, 2003). The total area and production under okra is reported to be 1148.0 thousand ha and 7896.3 thousand tons (FAOSTAT, 2011).

Okra can be eaten grated raw or cooked. The seeds of okra have been used as coffee substitute and edible oil could also be extracted from dried okra seeds. The amino acid profile of the seed indicates that it could be used to complement other partially complete protein sources such as soybean. Apart from its nutritive value, matured fruits and stems containing crude fiber are used in paper industry. Mucilaginous extracts of the green stem are commonly employed for clarifying sugar cane juice (Gopalan*et al*., 2007).

The okra plant requires warm temperatures and is unable to withstand low temperatures for long or tolerate any threat of frost. Optimum temperature is in the range of 21 to 30^{o}C, with minimum and maximum temperatures of 18^{o}C and maximum 35^{o}C respectively (Abd El - Kader *et al*., 2010).

The yield of okra could reach as high as 30 t ha^{-1}, but in most of the developing countries it is very low (1.77 t ha^{-1}) as compared to the yield of other agriculturally developed countries of the world (Whitehead and Singh, 2000). Okra production and productivity is seriously affected due to the use of low yielder local varieties, sub optimal plant density, inappropriate planting date, soil fertility, heavy attack of various insect pests and weeds. Maintaining optimum plant population and nitrogen fertilization dose are most important elements in improving productivity of okra. Optimum plant density is the key element for higher yield of okra, as plant growth and yield are affected by inter- and intra-row spacing (Chadha, 2002). Suitable plant spacing can lead to optimum yield but incorrect plant spacing could result in relatively low yield and poor quality fruits (Moniruzzaman *et al*., 2007). It has been reported that optimum plant population is the key element for higher yields of okra, as plant growth and yield are affected by intra and inter- row spacing (Amjad *et al*., 2001). The plant spacing for okra production suggested by different authors ranges from 20 to 40 cm between plants and 30 to 60 cm between rows (Hossain *et al*., 2001; Rastogie *et al*., 1987).

The plant density affects crops growth, yield components and yield of okra crop. The finding report of Rajendra *et al*., (2013) indicated that the highest plant height in the closest (30 cm x 45 cm) plant spacing while lowest plant height was observed in the widest, but the reverse was true for number of branches and number of leaves. The report of Rajendra *et al*., (2013) also indicated that maximum number of fruits and fruit yield per plant was obtained in the widest (60 cm x 45 cm) plant spacing**.** The finding conducted in Ethiopia around Humera were also indicated that the maximum plant height at flowering (85.74 cm) was observed when plants were spaced at 30 cm x 15 cm; however, the lowest plant height (64.16 cm) was obtained from the wider spacing (75 cm x 30 cm). The maximum (25.75) and minimum (14.31) number of green pods per plant were obtained in plants spaced at 75 cm × 30 cm and 30 cm × 15 cm, respectively. The highest green pod yield ha^{-1} (20.65 t) was obtained from plants spaced at 45 cm x 25 cm, which was statistically similar with those at 45 cm x 30 cm, while the lowest green pod yield per hectare (12.86 t) was obtained from plants spaced at 30 cm x 15 cm. (Haile *et al*., 2016). Amanga, (2014) reported that continual increase in green pod yield ha^{-1} from the lowest, 75 cm x 30 cm to the highest density of 45 cm x 25 cm of plant spacing at Gambella. Depletion and/or shortage of nitrogen in crop results either the crop will not able to maintain its leaf area expansion rate or cannot maintain its leaf and plant N concentration. Either of this will have effects on crop growth and production of economic products. Therefore proper attention must be given to nitrogen nutrients while planning a project on plant nutrition (Khalil, 2006). Nitrogen rates above 80 kg/ha adversely a□ected the yield of okra (VRIC, 2015). The research conducted in Sudan by Atif and Nahed (2016) revealed that increase in nitrogen fertilizer from the control (0 N) to 160 kg N ha^{-1} significantly increased fruit weight per plant from 140.99 to 582.79g and total yield from 3.72 to 6.73 t ha^{-1}, respectively. The research conducted at Gambella showed the application of nitrogen fertilizer increased the plant growth, delayed flowering and fruit setting of okra. It was also reported that the maximum fresh pod weight yield (46.14 t ha^{-1}) was obtained from the application of nitrogen fertilizer rate of 46 kg N ha^{-1} and from plants spaced at 45 cm x 30 cm, whereas, minimum fresh pod weight yield (34.52 t ha^{-1}) was attributed due to spacing of 45 cm x30 cm from plots without nitrogen application (Amanga, 2014).

There is no complete record on production area and production of okra in Ethiopia, but it is a traditional crop in south western, western and north western Ethiopia (Miheretu *et al*., 2014). The agro-ecological conditions of Ethiopia are favorable for home garden and commercial production of okra, the overall national production and consumption is negligible and the crop has been considered a minor crop which is traditionally cultivated in some parts of the country like Benishangul Gumuz, Gambella and Humera. In Ethiopia the study of okra agronomic practice is yet at beginning. To the best of our knowledge, there is no recommendation has been made for agronomic practices of okra in Benishangul regional state particularly around Assosa. In Assosa, okra crop is traditionally produced by the farmers and products reach up to 8-10 t ha^{-1} (BGRSBA, 2016). But reports are available for okra that indicate the potential of obtaining up to 30-40 t ha^{-1} tender fruit yield with optimum plant spacing and nitrogen fertilizer application (Amanga, 2014; and Whitehead and Singh, 2000). Therefore, the low yield from okra at Assosa might be due to the inappropriate use of plant spacing and production without fertilizer application. In recognition of the economic importance of okra in the study area, the potential of the crop in mitigate food insecurity and alleviate malnutrition in Ethiopia, and the absence of recommendation for plant spacing and nitrogen fertilizer at Assosa to increase the productivity of the crop, this study was undertaken with the following objectives.

Objectives

i) To assess the effect of inter-row spacing and rates of nitrogen fertilizer on growth, yield components and yield of okra, and

ii) To asses economically beneficial combination of inter-row spacing and nitrogen rate.

2. Materials And Methods

2.1. Description of the Study Area

The experiment was conducted in Benishangul Gumuz Regional State, at Assosa Agricultural Technical Vocational Education and Training College (ATVET), in the 2017 cropping season under rain-fed field conditions. The study site is located at 10^0 $02^'$ $05^"$ N latitude and 34^0 $34^'$ $09^"$ E longitudes and at altitude of 1467 meters above sea level. The study area is situated East of Assosa town and West of Addis Ababa about 14 km and 653 km distance, respectively. The area experiences a unimodal rainfall pattern and has annual total rainfall of about 1266.5 mm. The rainy season occurs from May to October and the maximum rain is received between the months of July and August. The minimum and maximum temperatures are 16.75^{O}C and 27.75^{O}C, respectively. The soil type of the area is *Nitosols*, which is dark reddish brown to dark red in colour (AARC, 2015).

2.2. Description of Experimental Materials

2.2.1. Planting material

A farmer's variety of okra known locally by the name of 'Bamia' was used as a planting material. The cultivar has been used by farmers in the region for a very long time and it takes about 2-4 months to mature under Assosa condition. The types of '*Bamia'* farmer cultivar were used.

2.2.2. Fertilizer source

Nitrogen fertilizer was used as one factor that can alter the growth, yield components, and yield of okra crop. Urea was used as source of nitrogen fertilizer which was attained in buy from Vicinity Farmers multipurpose Primary Co-operative (FMPC).

2.3. Treatments and Experimental Design

The treatments consisted of three inter-row spacing (30 cm, 45cm and 60 cm) and five levels of mineral nitrogen fertilizer rates (0, 23, 46, 69 and 92 kg N ha^{-1}). The experiment was laid out as randomized complete block design in a factorial arrangement and replicated three times. All other agronomic packages were applied equally for all treatments.

2.4. Experimental Procedures and Crop Management

The experimental field was ploughed twice. The first ploughing was conducted by a tractor and the second by oxen to get fine tilth. Then, individual plots in accordance with the layout plan, was manually levelled. Plots size was 3.6 m x 2.4 m. The spacing between each plot and each block was 0.8 m and 1m, respectively. There were 12, 8 and 6 rows in plots having 30, 45 and 60 cm row spacing, respectively. Intra-row spacing (between plants within a row) was 30 cm w used for all plots. Thus, there were 111111, 74074 and 55555 plants ha $^{-1}$, respectively under, 30 cm, 45 cm and 60 cm row spacing. Healthy seeds were planted manually by placing two seeds per hill which was thinned later after to one plant at 2-3 true leaf stage. Whole amount of phosphorus (46 kg P_2O_5 ha^{-1}) in the form of Triple Super phosphate (46% P_2O_5) and half of the nitrogen (in the form of Urea) as per the treatment was drilled in rows at the time of planting. The remaining nitrogen was side placed around 5 cm away from the plant base at 50% flowering stage.

The outer most three rows on both sides of the plots with 30 cm row spacing, two rows on both sides of plots with 45 cm row spacing and one row and two on each side of plots with 60 cm row spacing were taken as border rows. Whereas; one plant at both end of all rows in plots were considered as border plants. Therefore, no data was taken on these plants. Thus the net plot size was 1.8 m x 1.8 m under all the row spacing. All the other packages of practices except fertilizer were followed uniformly in all plots. Tender fruit were harvested at interval of 3-6 days.

2.5. Soil Sampling and Analysis

Soil samples were collected in order to know the physical and chemical properties of the soils of the study area. Samples were collected from the entire experimental site in zigzag pattern from 0 to 30 cm depth of soil using an auger. Then all samples were mixed together in order to get one composite sample weighing 1kg for determination of selected soil properties. The composite soil sample was analysed for soil pH at 1:2.5 soils to water ratio using a glass electrode attached to pH digital meter. Organic matter using Walkley and Black method (1934), total N (total nitrogen) as described by Landon (1991), available P according to the methods of Olsen and Dean (1954), soil cation exchange capacity (CEC) was determined by ammonium acetate method (Cottenie, 1980) and soil texture using Bouyoucos hydrometer method (Bouyoucos, 1951). The soil analysis was done at Assosa Soil laboratory.

2.6. Data Collection

2.6.1 Crop phenology

Fifteen days after the crop emergence, five plants in the net plot area of each plot were randomly tagged to record all the observations except crop stand and yield.

Days to 50% flowering: It was recorded as the number of days from plant emergence to when 50% of the plants in a plot produce flower.

Days to tender fruit setting: The total number of days taken from emergence to the stage at which 50% of the plants in each experimental plot set at least one pod per plant was recorded.

2.6.2. Growth Parameters

Plant height (cm): Plant height was taken three times at 30 days after emergence (DAE), at flowering, and at last picking from 5 plants with meter from ground level to the tip of main shoot.

Canopy spread: The canopy spread was measured by putting two sticks at the four crossed side of 5 plants from each plot at physiological maturity and average was done for one plant.

Total number of branches per plant: This was determined by counting the total branches of 5 sampled plants at physiological maturity and average was computed.

Length of tender fruit: The length of green pod collected from all 5 sampled plants was measured and average length was computed in cm.

Diameter of green pod: The collected green pod from 5 sampled plants was measured from centre portions of the pods and their average was taken.

Duration of harvest: This was taken as the number of days from the first picking to the last picking.

Number of Harvest: The total number of harvest was determined for each samples of treatment from the first harvesting to last harvesting was counted.

2.6.3. Yield and yield components

Stand count: The number of plants in the net area of each treatment was counted fifteen days after crop emergence and at the time of last harvest.

Number of green pods per plant: The average number of green pods collected from 5 sampled plants was computed by summing up all pods harvested.

Weight of green pod: Average weight (g) of a single pod was determined by taking weight of pods from 5 sampled plants at all harvests were divided by number of total pods in sampled plants.

Green pod yield per plant (kg): Yield of green pod per plant was determined by summing and averaging the weight of green pods harvested from 5 sampled plants at all picking times.

Green pod yield (ton/ha): Yield obtained at each harvest from the net plot area was summed up and converted in to a hectare basis and expressed as total yield (t ha^{-1}).

2.7. Regression Analysis

Linear regression analysis was conducted to compare which main factor (inter-row spacing and nitrogen fertilizer) had more effect on fruit yield and determine the rate of increase in fruit yield as the two factors levels changes.

2.8. Partial Budget Analysis

To assess the costs and benefits associated with inter-row spacing and nitrogen fertilizer the partial budget analysis technique as described by CIMMYT (1988) was applied on the yield results. Economic analysis was done using the prevailing market prices for inputs at planting and growing, and for outputs at the time crop harvested.

The cost related to vary due to nitrogen fertilizer and inter-row spacing was considered for all treatments due to the observed significant cost difference among the treatments. The economic analysis was based on the formula developed by CIMMYT (1988) and given as follows:

Gross average tender fruit yield (kg ha^{-1}) (AvY): is an average yield of each treatment.

Adjusted yield (AjY): is the average yield adjusted downward by a 10% to reflect the difference between the experimental yield and yield of farmers. It was calculated as:

AjY = AvY- (AvY x 0.1)

Gross field benefit (GFB): was computed by multiplying field/farm gate price that farmers receive for the crop when they sale it as adjusted yield.

GFB = AjY*field/farm gate price for the crop

Total cost: are the cost of nitrogen fertilizer, cost of seed, cost of nitrogen fertilizer application and cost of harvesting for the experiment, the costs of other production practices such as labor cost for land preparation, planting, weeding and chemicals were considered as equals for all treatments.

Net benefit (NB): was calculated by subtracting the total costs from gross field benefits for each treatment.

NB = GFB – total cost

Marginal return (MR): is the measure of increasing in return by increasing input.

Marginal rate of return (MRR %): was calculated by dividing change in net benefit by change in cost.

$$MRR = \frac{\Delta NB}{\Delta TC} \times 100$$

2.9. Data Analysis

The various agronomic data collected were subjected to analysis of variance using statistical procedures as described by Gomez and Gomez (1984) using SAS Version 9.3 for two factors in RCBD. The differences between and among treatment means were compared using least significance difference (Fishers' LSD) test at 5% of significance when the ANOVA shows the presence of significant difference.

3. Results And Discussion

3.1. Soil Characteristics

The soil in study area has pH of5.6, which is moderately acidic. The organic carbon content (5.32%) fall under the category of very high according to the rating of Tekalign Tadese (1991) who classified soil organic percentages of < 1.0, 1.0-1.71, 1.72-3, 3.1-4.29 and > 4.3 as very low, low, medium, high and very high, respectively. The soil of the study area is with medium total nitrogen (0.45%) content in accordance with the rating of Landon (1991) who classified soils having total N of greater than 1.0% as very high, 0.5-1.0% high, 0.2-0.5% medium, 0.1-0.2% low and less than 0.1% as very low in total nitrogen content. Available Phosphorous was content of 6ppm, which is low according to the classification of Olsen *et al*. (1954) who classified available P > 25, 18-25, 10-17, 5-9, < 5 ppm were classified as very high, high, medium, low and very low, respectively. The study site has CEC of 6.82meq/100, which is low according to rating of Landon (1991) who classified soils having CEC of > 40, 25-40, 15-25, 5-15, < 5 meq/100g as very high, high, medium, low and very low, respectively. The soil texture of the study site was 21 %, 36 % and 43 %; sand, clay and silt content and the textural class of soil being Clay loamy (Table 1).

Table 1. Pre-sowing soil physico-chemical properties of the experimental site

chemical properties	Content	Rating	Source
Soil pH	5.6	Slightly acidic	FAO (2008)
OC (%)	5.32	Very high	Tekalign (1991)
Total N (%)	0.45	Medium	Landon (1991)
Available P (ppm)	6	Low	Olsen *et al*. (1954)
CEC (meq/100)	6.82	Low	London (1991)
Soil Texture	%		
Sand (%)	21		
Clay (%)	36		
Silt (%)	43		
Textural Class	Clay Loamy		

OC=organic carbon, OM= organic matter, TN=Total nitrogen and CEC= cationexchange capacity

3.2. Crop Phenology

Number of days to 50% flowering and pod setting were considered as crop phenology of okra. Both characters of okra were significantly (P<0.05) influenced by inter-row spacing and nitrogen fertilizer application. However, the interaction of the two factors (inter-row spacing and nitrogen fertilizer) did not show significant effect on phenology of the crop (Appendix Table 1). Significant effect of plant spacing and nitrogen fertilizer application on okra flowering and maturity have been reported by many authors (Singh and Singh, 2000; Nehra *et al*., 1995; Nagwa, 2012). However, the non-significant effect of the interaction between the two factors (inter-row spacing and nitrogen fertilizer) was in contrast to the results reported by the authors. Haile *et al*. (2016) and Ali (1999) also reported the significant effect of intra and inter-row spacing on days to flowering in okra.

Days to 50% flowering and pod setting of okra increased with the increased inter-row spacing from 30 cm to 60 cm. Flowering and pod setting in okra were delayed in plants grown at 60 cm inter-row spacing. However, plants at inter-row spacing of 45 cm and 60 cm did not show significant difference on the number of days required to attain 50% flowering. The delayed pod setting in plants at row spacing of 60 cm was significantly different from days to pod setting in plants at row spacing of 30 and 45 cm. The difference between early and delayed flowering and pod setting in okra was only about 4.22% and 5.95% days, respectively (Table 2). The observed early flowering and pod setting of okra at closest inter-row spacing might be escape mechanism of the crop from stress in this case competitions of plants for resource like nutrient, moisture and light. Flowering in okra is continuous and highly dependent upon biotic and abiotic stress. The plant usually bears its first flower one to two months after sowing and fruits are growing quickly after flowering (Tripathi *et al*., 2011). Haile *et al*. (2016) also found that plants spaced at 30 and 15 cm inter and intra-row spacing, respectively, took minimum days to flower which was about 42 days, while the maximum days for flowering of okra (about 45 days) was observed in plants spaced at 75 and 30 cm inter and intra-row spacing, respectively. The authors also observed minimum days to 50% pod setting in plants at closest spacing but at the wider spacing plants were late to bear pods. Ali (1999) also reported that early flowering was observed in plants with closest row to row and plant to plant spacing than plants in widest spacing.

Plants grown without nitrogen fertilizer had significantly lowest mean days to 50% flowering and pod setting though it had non-significant difference with plants that received 23 kg N ha^{-1} for days to 50% flowering and plants received 23 and 46 kg N ha^{-1} for days to 50% pod setting (Table 2). Mean days to 50% flowering and pod setting gradually increased with the increased rates of nitrogen from 0 to 92 kg N ha^{-1} that highest mean days to 50% flowering is increased by about 7.75 % and pod setting increased by about 6.78 % over the control attained at rate of nitrogen fertilizer application respectively. This might be due to nitrogen nutrient that induced other vegetative growth rather than reproductive part. The results of this study is in agreement with the findings of Amanga (2014), who indicated application of nitrogen at the rate of 46 and 69 kg N ha^{-1} led to the longest days to 50%flowering as compared to the control treatment. Dwivedi *et al.* (1994) and Ambare *et al.* (2005) found that maximum 50% flowering in okra plants that received highest rates of 150 and 100 kg N ha^{-1}, respectively.

Table.2. Effect of inter-row spacing and nitrogen fertilizer on days to 50% flowering and pod setting of okra at Assosa in 2017

Treatment Inter-row spacing (cm)	Days to 50% flowering	Days to 50% pod setting
30	77.40^{b}	87.33^{b}
45	79.60^{ab}	88.73^{b}
60	80.67^{a}	92.53^{a}
LSD (0.05)	2.38	1.74
Nitrogen fertilizer (kg ha^{-1})		
0	76.00^{c}	86.89^{c}
23	77.78^{bc}	88.56^{bc}
46	79.78^{ab}	88.78^{bc}
69	80.67^{ab}	90.67^{ab}
92	81.89^{a}	92.78^{a}
CV (%)	4.02	2.62
LSD (0.05)	3.08	2.26

Mean values with similar letter (s) in each column and character had non-significant difference. CV (%) = coefficient of variation and LSD (0.05) = least significant difference at P<0.05.

3.3. Plant Height, Number of Branches and Canopy Spread

The effect of inter-row spacing and nitrogen fertilizer on plant height, number of branches per plant and canopy spread were evaluated. Plant height at flowering and at the end of the harvest, and canopy spread were significantly influenced only by inter-row spacing, while number of branches per plant was significantly affected by inter-row spacing, nitrogen fertilizer and the interaction of the two factors (Appendix Table 1). The significant effect of plant spacing (inter and intra-row spacing) on plant height of okra was reported (Singh *et al.,* 2002; Gupta, 1990). Many authors also reported the significant effect of plant spacing on plant height and number of branches per plant in okra (Haile *et al*., 2016; Ekwu and Nwokwu, 2012; Ijoyah *et al.,* 2010; Uddin *et al.,* 2006). In contrast, Singh and Singh (2000) reported that plant height was significantly influenced by nitrogen fertilizer and interaction of plant spacing but not affected by plant spacing. Ambare *et al.* (2005) also reported increasing levels of nitrogen significantly increased the plant height and number of branches plant^{-1}.

Plants attained significantly highest height at 30 cm inter-row spacing both at flowering and end of crop harvest. The height of plants tends to reduced as inter-row spacing increased, however, the height of plants measured at flowering and end of crop harvest did not show significant differences at inter-row spacing of 45 and 60 cm. The canopy of okra plants attained the maximum spread (diameter) at inter-row spacing of 60 cm whereas plants at narrow inter-row spacing of 30 cm had canopy spread reduction by about 30.68% compared to the use of 60 cm inter-row spacing (Table 4). The canopy spread was increased as the inter-row spacing increased probably due to availability of open space and less competition for resources within plants under wide inter-row spacing.

The present study result showed that maximum plant height at both flowering and end harvest due to 30 cm inter-row spaced which was in reduction by about 20.68% and 15.99% compared to wider inter-row (60 cm) spaced plants at flowering and end harvest respectively. These results could be due to less space available in the narrowest spacing, which discourages growth of lateral branches and favors plants to grow upward in competition for light. The current study result was in agreement with the report of Pedersen (2008) who indicated that when plants are spaced too closely, they grow tall to reach for the light, developing long, scrawny branches that tend to be weak; ultimately, plants do not produce as many leaves, flowers, fruits or seeds as compared to plants that have optimum light. The result of the present study was in conformity with that of Haile *et al.* (2016), who reported that plant height showed an increase with decrease of both inter-and intra-row spacing. Navdeep and Daljeet (2016) reported also in which in agreement indicated that as plant population increase plant height increase. The result of the authors indicated, at increased plant population the plant height was high as they observed that, intra-row 10cm spacing results in maximum average height of plant (91.3 cm). However, the minimum height (87.5 cm) was recorded under the 20 cm intra-row spacing.

Table.3. Effect of inter-row spacing on plant height and canopy spread of okra at Assosa in 2017

Treatment	Plant height (cm)			Canopy spread (cm)
Inter-row spacing (cm)	30 days after emergence	At flowering	End of harvest	
30	13.87^{ns}	104.15^{a}	173.92^{a}	67.73^{c}
45	13.20^{ns}	86.89^{b}	150.62^{b}	82.79^{b}
60	12.32^{ns}	82.61^{b}	146.11^{b}	97.77^{a}
CV (%)	19.09	9.82	14.35	18.09
LSD (0.05)	1.8	6.70	16.84	11.17

Mean values with similar letter (s) in each column and character had non-significant difference. CV (%) = coefficient of variation and LSD (0.05) = least significant difference at P<0.05.

The number of branches per plant increased due to interaction effect (inter-row and nitrogen) of the main factors (Table 4). The maximum number of branches per plant were counted at inter-row spacing of 60 cm in combination with 92 kg N ha^{-1} application, which was in statistical parity with the row spacing of 45 cm in combination with 69 kg N ha^{-1} and 92 kg N ha^{-1}; and inter-row spacing of 60 cm with application of 46 and 69 kg N ha^{-1}. The minimum number of branches per plant was obtained from 30 cm inter-row spacing without nitrogen fertilizer application (control). The production of more branches at the wider inter-row spacing might be due to the efficient utilization of available resources (nutrients, water and light energy) by the plants that could favor more photosynthesis and allocation of carbohydrate for all growth points as compared to the closest inter-row spacing. The result revealed that as inter-row and nitrogen fertilizer rates increase number of branch per plant increase and vice versa.

In agreement with the present study, the finding of Amanga (2014) indicated the maximum number of branches (2.93) was recorded from interaction of plant populations grown at the plant spacing of 60cm x 30 cm and application of 46 kg N ha^{-1}, whereas minimum number of branch per plant (1.9) was obtained under row spaced and nitrogen interaction of 60x20cm and 0 kg N ha^{-1} respectively. In line with the present study, Ibeawuchi *et al.* (2005) reported that wider row spacing (90x50cm) attributed maximum number of branch (7) and closest row spaced (30x50cm) okra plant showed minimum (3) branch per plant. Supporting current study Haile *et al.* (2016) reported that maximum number of branches per plant (2.16) was obtained from the widest plant spacing combination (70 cm x 30 cm), whereas minimum numbers of branches per plant (0.28) were recorded from the narrow spacing combinations of 30 cm x 15 cm.

Table.4. Interaction effect of inter-row spacing and nitrogen fertilizer on number of branches in okra at Assosa in 2017

	Inter-row spacing (cm)		
Nitrogen (kg ha^{-1})	30	45	60
0	0.67^{f}	1.20^{e}	2.47^{bc}
23	0.80^{ef}	1.73^{d}	2.33^{bc}
46	0.87^{ef}	2.27^{c}	2.58^{abc}
69	1.00^{ef}	2.80^{ab}	2.80^{ab}
92	1.07^{ef}	2.73^{abc}	3.00^{a}
CV (%)	15.12		
LSD (0.05)	0.48		

Mean values with similar letter (s) in column and row had non-significant difference. CV (%) = coefficient of variation and LSD (0.05) = least significant difference at P<0.05.

3.4. Duration and Number of Harvest

Duration (period) of harvest in days and number of harvest were highly significantly (P<0.01) affected both by inter-row spacing and nitrogen fertilizer, but not significantly influenced by the interaction of the two main factors. Stand count at harvest was not significantly influenced either of the two main factors or at the interaction of the two (Appendix Table 1).

The maximum duration of harvest in days and maximum number of harvests were observed in plants at inter-row spacing of 60 cm while the minimum duration/period of harvest (days) and minimum number of harvests were observed in plants at 30 cm inter-row spacing (Table 5). Duration and number of harvests in plants at all inter-rows spacing were significantly different from each other. The duration and number of harvest increased by about 25.26 % and 26.21 % due to inter-row spaced at 30 cm as compared to 60 cm inter-row spaced plants respectively. The increased duration and number of harvests as the inter-row spacing increased might be due to the availability of sufficient resources for the plants that support the prolonged vegetative growth of the crop which incurred continuous flowering and thereby production of fruits that extended period of harvest and number of fruits picking from plants.

The application of nitrogen fertilizer rate of 69 kg N ha^{-1} significantly increased the period and number of harvests but it was statistical parity with application of 92 kg N ha^{-1} application. The growing of okra plants without nitrogen fertilizer had significantly lowest period of harvest and number of harvests. The duration of harvest and number of harvests extended by about one week and one or two fruits picking in plants which received high rate of nitrogen (69 and 92 kg N ha^{-1}) application as compared plants grown without fertilizer. Generally as nitrogen application increase from 0 to 69 kg N ha^{-1} the period and number of harvest increased. The increased in period of harvest and number of harvest under higher levels of nitrogen might be attributed to increased availability of nitrogen for structural component of protein molecules. The protein molecules might have increased synthesis of protein and carbohydrates in favour of increasing cell division and elongation. The sufficient nitrogen supply might hasten other vegetative growth and continuous flowering which leads to prolonged period of harvest and number of harvest.

Consistent with the results of the present study, Khan *et al*. (2010) reported that the height, number of fruits per plant and number of branches per plant of sweet pepper in response to increased application of nitrogen fertilizer up to 150 kg N ha^{-1}. In line with current study, Bin-Ishaq (2009) who observed that increasing N application rate up to 45 kg N ha^{-1} was associated with significant progressive increases in number of branches per plant.

Table.5. Effect of inter-row spacing and nitrogen fertilizer on period of harvest and number of harvests in okra at Assosa in 2017

Treatment	Period of harvest (days)	Number of harvest (frequency of fruits picking)
Inter-row spacing (cm)		
30	26.13^{c}	6.60^{c}
45	30.20^{b}	7.67^{b}
60	32.73^{a}	8.33^{a}
LSD (0.05)	1.7	0.48
Nitrogen (kg ha^{-1})		
0	25.22^{c}	6.33^{c}
23	26.78^{c}	6.67^{c}
46	30.00^{b}	7.56^{b}
69	33.89^{a}	8.67^{a}
92	32.56^{a}	8.44^{a}
CV (%)	7.63	8.54
LSD (0.05)	2.19	0.62

Mean values with similar letter (s) in each column of each treatment and character had non-significant difference. CV (%) = coefficient of variation and LSD (0.05) = least significant difference at P<0.05.

3.5. Fruit Characteristics

Tender fruit weight (g) was highly significantly (P<0.01) influenced by inter-row spacing, nitrogen fertilizer and the interaction of the two factors. However, length and diameter of tender fruits (cm) significantly influenced neither by the two main factors (inter-row spacing and nitrogen fertilizer) nor the interaction of the two factors (Appendix Table 1). In line with the current study, the non- significance of length and diameter of tender fruits was reported by Ijoyah *et al*., (2010). However, the present result contradicted with the finding of Moniruzzaman *et al*., (2007) who reported pod length and pod diameter significantly influenced due to plant spacing. These conflicting results might be due to the difference in the environmental pattern of the study locations and to the variation in the genetic potential of the variety used.

The maximum weight of tender fruit was recorded from inter-row spaced at 60cm in combination with the application of nitrogen fertilizer rate at 92 kg N ha^{-1}, whereas; the minimum weight of tender fruit was obtained from combination of inter-row spaced at 30cm and 0 kg N ha^{-1} (Table 6). In agreement with the results of the current study, other studies also reported the significant effect of plant spacing, nitrogen fertilizer and the interaction of the two on weight of tender fruits per plant (Anwar *et al*., 2016, and Navdeep and Daljeet [2016]).

The result of this study showed that the interaction effect of the two main factors (inter-row space and nitrogen fertilizer) on fruit weight increases by about 61.65 % due to combination effects of inter-row spaced at 30 to 60 cm and 0 to 92 kg N ha^{-1} respectively. This highest mean pod weight at the widest inter-row spacing and highest nitrogen fertilizer might be attributed due to more nutrient and moisture availability for better tender fruit weight and providing sufficient assimilate for the development of pods as enough resource might availed from source to sink ultimately resulting in higher pod weight. In agreement with current study, Navdeep and Daljeet (2016) reported that highest pod weight of 10.2g obtained was due to interaction with N100 and S15, while lowest 6.2g pod weight was due to combined effect of nitrogen fertilizer rate 75 kg N ha^{-1} and Spacing 10cm. The result of the authors indicated that at higher nitrogen rate and lower plant population, the weight of fruit becomes increased.

Table 6. Interaction effect of inter-row spacing and nitrogen fertilizer on tender fruit weight of okra at Assosa in 2017

Treatment	Inter-row spacing (cm)		
Nitrogen (kg ha^{-1})	30	45	60
0	15.88^{d}	21.80^{bc}	22.09^{bc}
23	17.13^{d}	20.41^{c}	21.18^{bc}
46	17.13^{d}	22.55^{b}	22.42^{b}
69	17.42^{d}	21.38^{bc}	25.55^{a}
92	16.73^{d}	21.37^{bc}	25.67^{a}
CV (%)	5.1		
LSD (0.05)	1.75		

Mean values with similar letter (s) in columns and rows had non-significant difference. CV (%) = coefficient of variation and LSD (0.05) = least significant difference at P<0.05.

3.6. Number of Fruits and Fruit Yield per Plant

The analysis of variance showed that number of fruits per plant and weight of tender fruits per plant were highly significantly (P<0.01) influenced by inter-row spacing, nitrogen fertilizer and the interaction of the two factors (Appendix Table 1). In agreement with the results of the current study, other workers also reported the significant effect of plant spacing, nitrogen fertilizer and the interaction of the two on number of fruits and weight of tender fruits per plant (Haile *et al*., 2016; Navdeepand Daljeet, 2016; Birbal and Malik, 1996; Singh, 1988).

Number of tender fruit and fruit weight per plant of okra increased with the increased the interaction of main factor (inter-row spacing and nitrogen fertilizer rate) from 30 cm to 60 cm and 0 to 92 kg Nha^{-1}. Maximum Number of tender fruit and weight of tender fruit per plant in okra due to inter-row spaced at 60 cm combined with nitrogen rate of 92 kg $ha^{-1}$was increased by about61.65% and 238.89% compared to 30cm combined with 0 kg N ha^{-1} respectively. The highest number of tender fruit due to combined effect of IRS/N at 60cm/92 kg N ha^{-1} had statistical parity at 60 cm/69 kg N ha^{-1}, 60 cm/69 kg N ha^{-1} and 60 cm/23 kg N ha^{-1}. Whereas, the highest data recorded for weight of tender fruit $plant^{-1}$ due to combined effect of IRS/N at 60 cm/92 kg N ha^{-1} showed statistical similarity with combination effect at 60cm/69 kg N ha^{-1}. Whereas, the minimum recorded number of fruits and weight of fruit per plant (11.9 and 0.18 kg) respectively, as influenced by the two interactions were at 30cm inter-row spacing with 0 kg N ha^{-1}. The difference between number of fruit and weight of fruit in okra attained was about 12.09 and 0.14 kg, respectively (Table 6). The result indicated that at plants spaced at closest inter-row and nil nitrogen fertilizer reduces number of fruit and weight $plant^{-1}$.

The result of present study revealed that, increase in interaction of inter-row spacing 30 to 60cm and nitrogen fertilizer from nil to 92 kg ha^{-1} increase both character (number of fruit and weight of fruit per plant) because, at wider spacing and high nitrogen fertilizer rate, number of branch and weight of single fruit increase due to availability of sufficient resource. Navdeep and Daljeet (2016) reported that the highest number of pods per plant (40.2) was obtained with combination of spacing of 20 cm and nitrogen125 kg $ha^{-1}$and highest weight per plant (325 g) was with combination of spacing 20 cm and nitrogen 125 kg ha^{-1}; where closest spacing attributed 21.6 pods and 146.6 g pod weight plant ha^{-1} at spacing of 10 cm and nitrogen rate of 75 kg ha^{-1}. A similar trend of response had been earlier observed with okra crops (Atif and Nahed, 2016).

3.7. Fruit Yield per Hectare

The two main factors (inter-row spacing and nitrogen fertilizer) had highly significant (P<0.01) effect on tender fruit yield per hectare. However, inter-row spacing and nitrogen fertilizer did not interact to influence yield significantly (Appendix Table 1). In agreement with the result of current study, other researchers also indicated significant effect of plant spacing and nitrogen fertilizer on okra crop yield per hectare (Anwar. *et al*. 2016; Navdeep and Daljeet, 2016).

The fruit yield per hectare was increased with increase of inter-row spacing and nitrogen fertilizer; from 30 cm to 60cm and 0 to 92 $kgha^{-1}$, respectively. Maximum fruit yield due to response of IRS of 60 cm and 92 kg N ha^{-1} increased by about 30.48% and 29.34% over IRS 30 cm and control nitrogen respectively. The maximum recorded result as influenced by inter-row spacing and nitrogen fertilizer was statistically at par with yield attained at 45cm from 69 kg ha^{-1}, respectively (Table 7).

Table.7. Interaction effect of inter-row spacing and nitrogen fertilizer on number of fruits and weight of tender fruits per plant in okra at Assosa in 2017

Character	Number of fruits per plant		
Treatment	Inter-row spacing (cm)		
Nitrogen (kg ha^{-1})	30	45	60
0	11.19^{f}	16.15^{d}	21.54^{b}
23	12.18^{ef}	17.60^{cd}	23.09^{a}
46	12.37^{ef}	17.90^{c}	24.08^{a}
69	12.75^{e}	21.25^{b}	23.92^{a}
92	13.61^{e}	21.42^{b}	23.99^{a}
CV (%)		4.9	
LSD (0.05)		1.5	
Character	Weight of tender fruits per plant (kg)		
Treatment	Inter-row spacing (cm)		
Nitrogen (kg ha^{-1})	30	45	60
0	0.18^{g}	0.35^{e}	0.47^{c}
23	0.21^{fg}	0.36^{de}	0.49^{c}
46	0.21^{fg}	0.40^{d}	0.54^{b}
69	0.22^{fg}	0.45^{c}	0.61^{a}
92	0.23^{f}	0.46^{c}	0.61^{a}
CV (%)		7.12	
LSD (0.05)		0.05	

Mean values with similar letter (s) in columns and rows in each character had non-significant difference. CV (%) = coefficient of variation and LSD (0.05) = least significant difference at P<0.05.

The current study generated that the tender fruit yield per hectare result revealed that as both main factor **(**inter-row spacing and nitrogen fertilizer) increase IRS (30 to 60cm) and N (0 kg ha^{-1} to 92 kg ha^{-1}) the yield per hectare increase. The result is in line with the finding of Firoz (2009) who reported that increasing the rates of N from 0 to 40 or 40 to 80 kg N ha^{-1}, significantly increased total fresh pod yield and the mean fresh pod yield of okra. Increased in tender fruit yield with increase the main factor could have resulted from efficient utilization of resources leading to optimum yield component and yield characters which favoured higher tender fruit yield of okra. Amanga (2014) reported similar finding that indicate as row spacing and nitrogen increase, pod fresh yield ha^{-1} increase. The finding of Anwar (2016), on tomato wan in conformity with the present study showed that; maximum fruit yield ha^{-1} (27.96 t ha^{-1}) was produced by the plots having 90 cm row spacing whereas minimum yield (25.13 t ha^{-1}) was produced by the plots having 120 cm row spacing.

Table.8. Effect of inter-row spacing and nitrogen fertilizer on okra fruit yield per hectare at Assosa in 2017

Treatments Inter-row spacing (cm)	Tender fruit yield (t ha^{-1})
30	23.26^{b}
45	30.02^{a}
60	30.35^{a}
LSD (0.05)	1.34
Nitrogen (kg ha^{-1})	
0	24.08^{c}
23	25.64^{c}
46	27.80^{b}
69	30.74^{a}
92	31.12^{a}
CV (%)	6.41
LSD (0.05)	1.73

Mean values with similar letter (s) in each column of each treatment had non-significant difference. CV (%) = coefficient of variation and LSD (0.05) = least significant difference at P<0.05.

3.8. Regression of Inter-row Spacing and Nitrogen Fertilizer Rate with Fruit Yield

The main factors inter-row spacing and nitrogen fertilizer rate had significant influence on fruit yield of okra. However, the interaction of the two main factors had not significant effect on fruit yield (Table 8). Therefore, regression analysis was conducted to compare which main factor had more effect on fruit yield and determine the rate of increase in fruit yield as the two factors levels changes. The results of regression analysis are presented as figure (Figure 1a & b) for visual observation. The fruit yield of okra was determined by about 78.48% (R^2= 0.7848) with strong correlation (r=8859) between the yield and the increase of inter-row spacing. The regression was positive and significant at P<0.05 (P=0.03071) indicating as the relationship between inter-row spacing and fruit yield was linear. On the other hand, nitrogen fertilizer rate (kg/ha) was determined fruit yield by about 96.41% (R^2 =0. 9641) with strong correlation (r=9819) between the yield and the increased rates of nitrogen fertilizer (kg/ha). The regression was linear and highly significant at P<0.01 (P=0.0029). This showed that as the nitrogen fertilizer rate (kg/ha) increased from null to higher rate (92 kg/ha) the fruit yield was also increased linearly.

The results of regression analysis suggested that the application of nitrogen fertilizer (kg/ha) with increased rates had more influence than the inter-row spacing (cm) which was increased from narrow (30 cm) to wider spacing (60 cm). This might be due to the increased nitrogen fertilizer rate increase number of branches and utilization of proteineous metabolites for build up of new tissuesincrease number of pod and pod character for better yield. In agreement with the current study results, Navdeep and Daljeet (2016) also reported the increased in fruit yield due to nitrogen fertilizer from 75 kg ha^{-1} to 125 kg ha^{-1} was 49.6 q ha^{-1} and 74 q ha^{-1} respectively, whereas; yield obtained due to row spaced 10 cm to 20 cm was 49.6 q ha^{-1} and 53 49.6 q ha^{-1} respectively. The finding of the author showed that increased in nitrogen fertilizer had more influence than plant spacing.

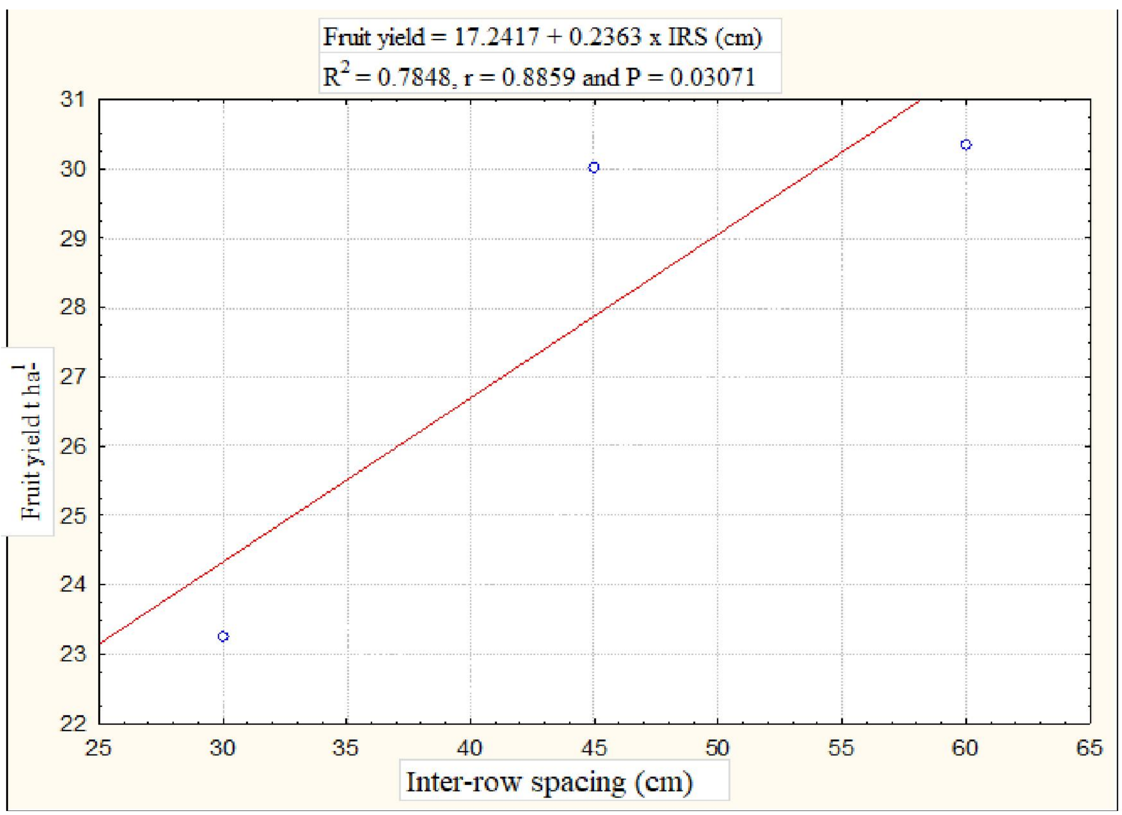

Figure 1a. Linear regression response of inter-row spacing on okra fruit yield.

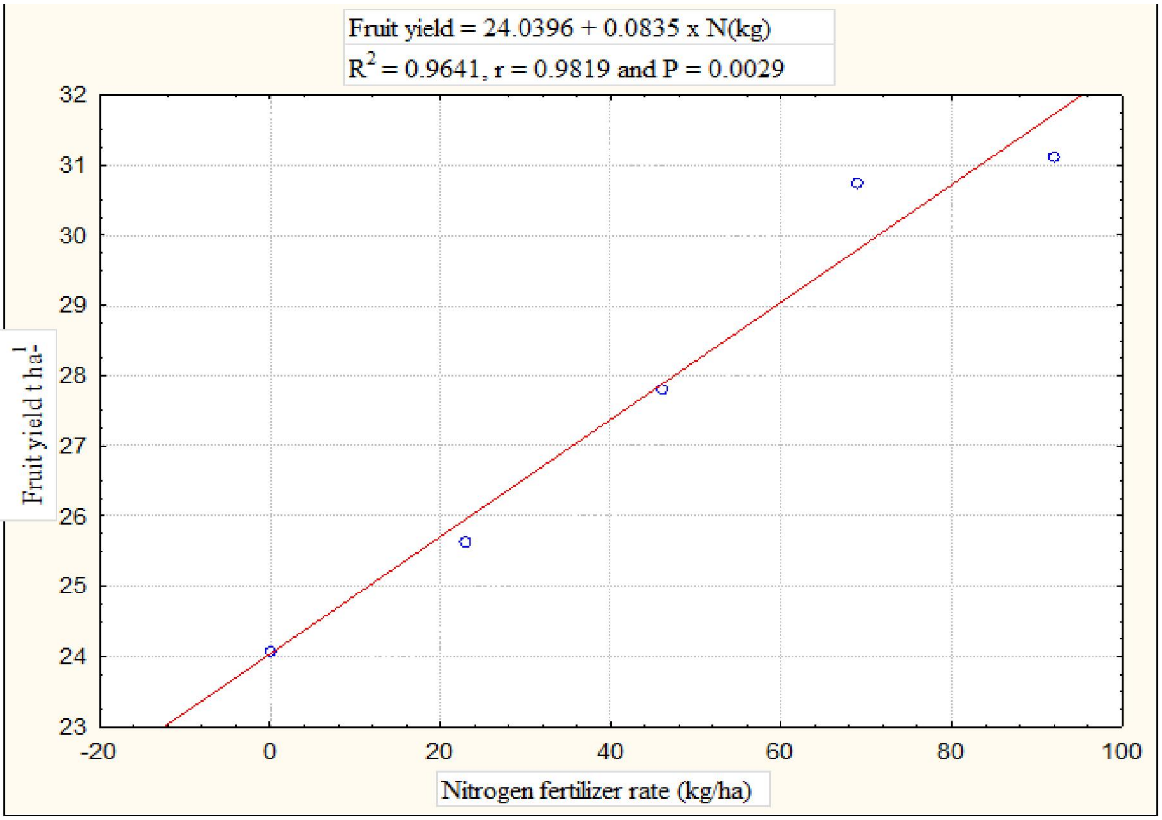

Figure 1b. Linear regression response of nitrogen fertilizer rate on okra fruit yield.

3.9. Partial Budget Analysis

The result of the partial budget analysis showed that highest net benefit of 290544.59 Birr ha^{-1} with MMR of 250%, was obtained from the plant inter-row spaced at 60 cm from application of 92 kg N ha^{-1} followed by 289044.59 Birr ha^{-1} from plant inter-row spaced 60cm in combination with69kg N ha^{-1}. Whereas, highest rate of marginal returns 5833.33% was obtained from plant inter-row spaced 60 cm in combination with 69 kg N ha^{-1} followed by 5550.00% from plant inter-row spaced at 45 cm combined with application of 69 kg N ha^{-1}. Therefore, the result revealed that use of plant inter-row spaced 60 cm combined with 69 kg ha^{-1} nitrogen fertilizer applications were effective as compared to the others.

Table.9. Summary of the partial budget response of okra to inter-row spacing and nitrogen fertilizer at Assosa, 2017

IRS/N kg ha^{-1})	Unadjusted yield (t ha^{-1})	Adjusted yield (t ha^{-1})	Total Revenue (ETB ha^{-1})	Total Variable cost (ETB ha^{-1})	Net return (ETB ha^{-1})	Marginal rate return (%)
30/0	19.71	17.74	177400	29111.08	148288.92	D
30/23	23.16	20.84	208400	29811.08	178588.92	D
30/46	23.53	21.17	211700	30411.08	181288.92	450.00
30/69	24.64	22.17	221700	31011.08	190688.92	1566.67
30/92	25.29	22.76	227600	31611.08	195988.92	883.33
45/0	26.11	23.5	235000	19407.39	215592.61	D
45/23	26.57	23.91	239100	20107.39	218992.61	D
45/46	29.89	26.9	269000	20707.39	248292.61	4883.33
45/69	33.66	30.29	302900	21307.39	281592.61	5550.00
45/92	33.89	30.51	305100	21907.39	283192.61	266.67
60/0	26.43	23.79	237900	14555.41	223344.59	D
60/23	27.21	24.49	244900	15255.41	229644.59	900.00
60/46	29.99	26.99	269900	15855.41	254044.59	4066.67
60/69	33.95	30.55	305500	16455.41	289044.59	5833.33
60/92	34.18	30.76	307600	17055.41	290544.59	250

IRS= inter-row spacing, N= nitrogen, D= Dominance

4. Summary And Conclusion

Sustaining product and productivity for higher yields and better quality can be achieved by fully exploiting the potential or biological yield of a crop at hand. However, this is only possible through improved crop management practices and varietal development.

Thus, reliable information on agronomic management practices such as appropriate inter- row and nitrogen fertilizer and crop response to this inter-row and nitrogen fertilizer and/or their interaction is quite important to come up with profitable and sustainable crop production and productivity. To achieve this, field research was undertaken to investigate the effect of inter-row spacing and nitrogen fertilizer rate on growth and yield component and yield of okra at Assosa, western Ethiopia, from May to October 2017 main cropping season. Three levels of inter- row spacing (30, 45 and 60cm) and five levels of nitrogen fertilizer (0, 23, 46, 69,92kg ha^{-1}) were adopted as treatments with three replications in factorial arrangement using randomized complete block design.

The main effect of inter-row spacing and nitrogen fertilizer were significant ($p<0.05$) on days to 50% flowering, days to pod setting, period of harvest, number of harvest and yield of tender fruit per hectare. Parameters like plant height at flowering and at last harvest were affected significantly ($p<0.05$) due to inter-row spacing main factor only. Whereas the main effects and interaction of different combination of inter-row spacing and nitrogen fertilizer rate were significant ($p<0.05$) on number of branch per plant, number of tender fruit per plant, weight of single tender fruit, weight of tender fruit per plant and yield of tender fruit per hectare.

The means of interaction (inter-row spacing x nitrogen fertilizer) revealed that the plants grown on wider inter-spacing and higher nitrogen fertilizer rate (60 cm x 92 kg ha^{-1}) resulted in the highest tender fruit yield $plant^{-1}$ (0.61 kg), being statistically at par with that of 60 cm x 69 kg ha^{-1}, inter-row spacing and nitrogen fertilizer respectively.

Concerning the yield on an area basis the highest tender fruit yield per hectare (30.35 t) was obtained when plants spaced at 60cm inter-row, being statistical par with 45cm inter-row spaced and the highest yield per hectare attained due to nitrogen fertilizer were (31.12 t) at highest nitrogen fertilizer rate 92 kg ha^{-1}, being non-significant with application at 69 kg N ha^{-1}. This implies that tender fruit yield per unit area and tender fruit yield per plant can be maximized with wider inter-row spacing and higher nitrogen fertilizer rate, also tender fruit weight $plant^{-1}$ and quality parameters like number of branch $plant^{-1}$, canopy spread, number of tender fruit $plant^{-1}$, weight of tender fruit be improved with wider spacing and increase in nitrogen nil to 92 kg ha^{-1}. So, this suggests the need to compromise between optimum yield and quality when selecting appropriate inter-row spacing and nitrogen fertilizer rate in okra.

In general, the study revealed a continual increase in tender fruit yield ha^{-1} from the narrowest inter-row spacing, 30 cm (11.11 plants m^{-2}) to the widest inter-row spaced 60 cm (5.55 plants m^{-2}) and as response of increase nitrogen fertilizer rate from nil to 92 kg ha^{-1}. Due to optimization of inter-row space, narrowest (30 cm) to the widest (60 cm) and nitrogen fertilizer from 0 kg to 92 kg ha^{-1}, an improvement of tender fruit yield of okra by about 30% can be expected at Assosa area.

The partial budget analysis revealed that the combination of the IRS/N rate of 60 cm/92 kg ha^{-1} recorded the highest economic benefit of 290544.59 Birr ha^{-1} with MRR 250%. However, based on the results of this experiment the inter-row spaced at 60cm with combination of 69 kg N ha^{-1}recorded economic benefit of 289044.59 Birr with MRR 5833.33%, which is higher than of combined effect of IRS/N rate at 60/92 kg ha^{-1}. Therefore, the use of inter-row spacing of 60 cm and nitrogen fertilizer rate of 69 kg N ha^{-1} could be tentatively recommended for optimum production of okra in the study. However, to make a conclusive recommendation, the research should be repeated over location and seasons in the study area.

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Appendices

Appendix Table 1: Mean squares from analysis of variance (ANOVA) for morphology traits of okra as influenced by inter-row spacing and nitrogen fertilizer at Assosa in 2017

Trait	Rep (2)	IRS (2)	N (4)	IRS x N (8)	Error (28)	CV (%)
Days to 50% Flowering	5.50^{ns}	41.62*	49.44**	2.51^{ns}	10.16	4.02
Days 50% Pod Setting	6.47^{ns}	108.6**	45.74**	7.29^{ns}	5.42	2.6
Height at 30DAE (cm)	2.75^{ns}	8.88^{ns}	6.48^{ns}	4.25^{ns}	6.28	19.09
Height at flowering (cm)	19.32^{ns}	1951.23**	54.70^{ns}	11.69^{ns}	80.31	9.82
Height at last harvest (cm)	95.93^{ns}	3340.44*	205.40^{ns}	91.19^{nS}	506.65	14.35
Number of branch plant^{-1}	0.06^{ns}	12.31**	1.14 **	0.27**	0.08	15.12
Canopy spread (cm)	316.78^{ns}	3382.66**	508.95^{ns}	87.48^{ns}	217.62	17.82
Period of harvest (days)	11.76^{ns}	166.29**	122.36**	4.79^{ns}	5.14	7.63
Number of harvest	0.87^{ns}	11.47**	9.69**	0.27^{ns}	0.41	8.54
Stand count	3.90 ^{ns}	0.30^{ns}	2.42 ^{ns}	1.59^{ns}	2.98	1.74
Number of tender fruitplant^{-1}	0.62^{ns}	450.62**	16.59**	2.90**	0.8	4.9
Length of tender fruit (cm)	14.58^{ns}	0.18^{ns}	2.39^{ns}	1.15^{ns}	3.07	8.99
Diameter of tender fruit (cm)	0.06^{ns}	0.10^{ns}	0.02^{ns}	0.06^{ns}	0.07	9.77
Weight of tender fruit (g)	0.09^{ns}	169.36**	6.00**	4.96**	1.1	5.1
Weight of tender fruitplant^{-1} (kg)	0.00^{ns}	0.43**	0.02**	0.00*	0	7.14
Yield of Tender fruit (ton ha^{-1})	1.44^{ns}	240.15**	85.84**	4.77^{ns}	3.2	6.41

Rep=replication, IRS=inter-row spacing, N=Nitrogen, CV=coefficient of variance and the number in par entice on the first row indicate the number of degree of freedom.

Appendix Table 2: Partial budget summary of treatments

Treatments	Nitrogen cost (ETB)	Seed cost (ETB)	Harvesting cost (ETB)	Fertilizer Application cost (ETB)	Total Variable Cost (ETB)
T1 (30/0)	0	1333.33	27777.75	0	29111.08
T2 (30/23)	500	1333.33	27777.75	200	29811.08
T3 (30/46)	1000	1333.33	27777.75	300	30411.08
T4 (30/69)	1500	1333.33	27777.75	400	31011.08
T5 (30/92)	2000	1333.33	27777.75	500	31611.08
T6 (45/0)	0	888.89	18518.50	0	19407.39
T7 (45/23)	500	888.89	18518.50	200	20107.39
T8 (45/46)	1000	888.89	18518.50	300	20707.39
T9 (45/69)	1500	888.89	18518.50	400	21307.39
T10 (45/92)	2000	888.89	18518.50	500	21907.39
T11 (60/0)	0	666.66	13888.75	0	14555.41
T12 (60/23)	500	666.66	13888.75	200	15255.41
T13 (60/46)	1000	666.66	13888.75	300	15855.41
T14 (60/69)	1500	666.66	13888.75	400	16455.41
T15 (60/92)	2000	666.66	13888.75	500	17055.41

Nitrogen: - 1kg =10 ETB, Seed:-1kg=150 ETB, Harvesting;-1plant =0.25ETB, Fertilizer application: - 100kg =600 ETB

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