**Effects of inter and intra row spacing on seed yield and yield components of sunflower at northwestern Gondar of Ethiopia**

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**ABSTRACT**

*An experiment on inter and intra row spacing were conducted to determine an optimum spacing for maximum seed yield of sunflower. The experiment was carried out at Metema and West- Armachiho districts in the year 2022/23 and 2023/24 main rainy seasons. Treatments consisted of factorial combinations of four inter rows (55, 75, 95, and 115 cm) and three intra rows (20, 30 and 40 cm) spacing and in randomized complete block design (RCBD) with three replications. Data on days to flowering, maturity, plant height, head diameter, head weight, number of seeds per head, thousand seeds weight and grain yield recorded and subjected to analysis of Variance (ANOVA). Results of this study showed that day to flowering, day to maturity, plant height, head diameter, number of seeds per head and thousand seeds weight were highly significantly (p < 0.01) affected by the main effect of inter- and intra-row spacing in combined over year and locations. The interaction between inter- and intra-row spacing significantly affected only head weight and grain yield of sunflower. The highest grain yield (2375.2 kg ha-1) were recorded from 75cm inter by 30cm intra-row spacing of sunflower. The lowest grain yield (1704.3 kg ha-1) were recorded from 115cm inter by 40cm intra-row spacing. The cost-benefit analysis revealed that the highest net benefit of 89671.4 Eth-Birr was obtained with the interaction effect of 75cm inter and 30cm intra row spacing. Therefore, the inter row spacing 75cm with intra row spacing 30 cm can recommended for optimum seed yield of sunflower in the low lands of Gondar and similar agro ecology.*

Key words: - *interaction, row- spacing, sunflower, yield*

**INTRODUCTION**

In Ethiopia, total edible oil consumption in fiscal year 2020/21 is projected at 630,000 metric tons, of which 90 percent is imported. Most of the oil consumed is palm oil, followed by sunflower oil and locally produced Niger seed oil. Small amounts of soybean, linseed, groundnut, and cottonseed oils are also consumed (USAD, 2021). The burden of importing edible oil is increasing from year to year due to population and economic growth (USDA, 2021). With increasing demand, limited domestic production and the country’s heavy reliance on imported oil, there have been supply shortages especially in urban areas. In addition, as some consumers become increasingly diet conscious, they are looking for healthier alternatives to palm oil. There is an increasing preference towards alternative edible oils containing non-saturated oils and fats. Most Ethiopian consumers prefer sunflower, niger seed, and soybean oils as healthier alternatives, and due to these changes in consumer preferences, consumption of sunflower oil has almost tripled over the last couple of years; palm oil has dropped considerably (USAD, 2021; Urugo *et al.,* 2021 ).

Sunflower is a wide spread oilseed crop of the world and it is almost grown in all continents. Europe, America and Australia accounts for 80% of the total production of the world whereas Asia contributes to 18% and the rest 2% from Africa (Damodaran and Hege, 2010). Sunflower was cultivated in an area of 25.3 million hectares with annual production and productivity of 53.94 million metric tons and 1410kg ha-1, respectively in the world, in the year 2021(FAO, 2021). In Ethiopia, it was cultivated in an area of 4,749.96 hectares with annual production and productivity of 5,150.5 tones and 1084.33kg ha-1, respectively in the year 2021(CSA 2022).

Sunflower is one of the most important oil crops in the world, because it offers advantages in crop rotation systems, such as high adoption capability, suitability to mechanization and low labor needs (Ramos et al., 2014). The sunflower oil can be used as a salad and cooking oil or in making margarine. Also it has been used as a source of commercial fiber, and the seeds are used in medicine as diuretic and in treating certain disorder of the respiratory track. The seeds cake makes a high quality cattle and poultry feed because of its high protein content (Baleseng *et al.,* 2023). El Naim and Ahmed (2010) reported that sunflower oil is healthier than most other food oils on the market. sunflower oil is generally considered a premium oil because of its light color, high level of unsaturated fatty acids and lack of linolenic acid, bland flavor an high smoke points, the primary fatty acids in the oil are oleic and linolenic (Typically 90 % unsaturated fatty acids), with the remainder consisting of palmatic and stearic saturated fatty acids.

Even though the crop has a high potential to become a competent oil crop in the country, much progress did not achieved in improving the agronomic practices (Alemaw and Gurmu 2023). Inappropriate agronomic practices especially inappropriate optimum plant population greatly affects the productivity of sunflower (Crnobarac *et al.,* 2012). Adequate plant population is an important for highest yields (Viorel *et al*, 2015). Sunflower will compensate for differences in plant populations and density through adjustments in head size. The number of plants per unit area is one of most important agronomic practice affecting the yield in sunflower (Ahmad *et al.*, 2010). However, this component of yield may vary dependent on the environmental conditions. Narrow rows make sunflower plants able to use in an efficient way the growing resources, respectively the solar radiation, water and nutrients, but this seems to be influenced by the specific environmental factors (Agegnehu *et al.,* 2023). Further increase in plant density may lead to a stable and even reduced seed yield affected by environmental factors (Ion *et al.*, 2015). The results on the highest yield and the plant density reported from different parts of the world are contradictory to each other. The higher yields were obtained by 100 thousand plants ha-1 (Beg *et al.*, 2007). However, different densities have been reported in different areas ranging from 45 to 75 thousand ha-1. The differences in plant density may cause significant variation in seed yield in semi-arid ecological conditions. The aim of this study was to determine the appropriate inter and intra row spacings of sunflower to obtain the highest seed.

**MATERIAL AND METHODS**

**Description of the study area**

A field experiment was conducted in Metema and West- Armachiho districts of west Gondar zone in Amhara region. The two locations are situated in the West Gondar zone. Both districts are the major producer of sunflower in the region. Sesame, sorghum, cotton and soybean were the dominant crops and dominated by vertisols. Metema district is located at 12°24’48’’ to 13°09’71’’ N Latitude and 36°15’19’’ to 36°64’71’’ E longitudes with an altitude ranging from 710 to 898 meters above see level. It is characterized with rain fall 700 to 1160 mm and temperature 12.6-36.1°c. West- Armachiho district is located at 13°10’09’’ to 13°70’36’’ N Latitude and 36°31’29’’ to 36°77’16’’ E longitudes with an altitude ranging from 570 to 860 meters above see level. It is characterized with rain fall 570 to 880 mm and temperature 14.6-38.1°c. The study areas characterized with mono-modal type of rainfall distribution pattern in which the rainy season commences in early June to ends in September.

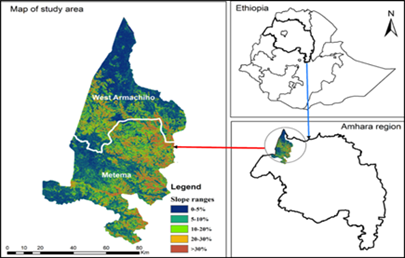


Fig1. Study area map

**Experimental Design and Treatments**

A factorial combination of 4 inter row spacing (55, 75, 95 and 115 cm) and 3 intra row spacing (20, 30 and 40 cm) were laid out in a randomized complete block design (RCBD) with three replications. The spaces between plots and replications were maintained 1m and 1.5m, respectively. The gross plot size was 4.5m x 4m (18m²). As per the treatments there were 8, 6, 5 and 4 rows for 55, 75, 95 and 115cm inter-row spacing, respectively. The number of plants in each row was 20, 13 and 10 for intra row spacing of 20, 30 and 40cm, respectively. The harvestable plot areas were 13.2 m2, 12m2, 9.6m2 and 8.4m2 for the row spacing of 55cm, 75cm, 95cm and 115cm, respectively. The outer most one row on both sides of the row spacing served as border rows for all row spacing

**Experimental Materials and Management**

Oissa variety was used as planting materials. NPS fertilizer rate of 50 kgha-1 was applied at sowing time. The seeds were planted on mid-June, by placing two seeds per hole at a specific inter and intra row spacing at a depth of about 5 cm and covered by 2.5 cm layer of soil for adequate emergence. One week after emergence thinning was done. The experimental sites were oxen-ploughed twice, harrowed and leveled by human labors to a fine tilt. All necessary agronomic management practices were done frequently throughout growing period. Weeding was done on appropriately three times. The first weeding was done 15 days after emergence, the second weeding on 25 days after the first weeding and the third weeding on 30 days after the second weeding. Harvesting was done after physiological maturity (the back of head turn yellow and the bract of head turn brown color) from net plot at full ripening. Matured heads were harvested and drying was done by setting the harvested heads in sacs until all heads dried by sun. Threshing was done by hand.

**Data Collection and Analysis:**

Data on days to flowering and maturity were collected in plot based and the remain parameter were collected in plant based. Ten randomly selected samples of plants in each plot from harvestable rows were taken to estimate plant height (PH), head diameter (HD), head weight (HW) and number of seeds per head (NSPH). Grain yield was collected from the net plot, and the number of seeds was counted. The grain yield and thousand-seed weight were then adjusted to a standard moisture content of 8% (on a wet basis) for uniformity and comparison purposes. Moisture content of the samples was determined using a moisture tester. To adjust the grain yield to 8% moisture content, the following equation was used

Where:

* Observed Yield: - is the measured yield at the current moisture content.
* Measured Moisture Content:- is the moisture content measured in the sample
* 8%:- The target moisture content to which you want to adjust.

The generated data were statistically analyzed by using R statistical software version 4.4.0. (Kabacoff, R. 2022). Significant pairs of means were separated using the Least Significant Difference Test (LSD) at 5% level of significance and used for mean separation for all agronomic parameters.

**Partial Budget Analysis:**

Partial budget analysis was performed to estimate the net profit from this cultural operation. The study employed methodologies outlined by CIMMYT (1988) to evaluate the economic viability of different spacing treatments of sunflower. Costs associated with seed, planting (row-making), and cultivation (weeding) were calculated on a per-hectare basis in Ethiopian birr (ETB). The partial budget analysis utilized mean grain yields from each treatment, adjusting the grain yield downward by 10%, reflecting the yield farmers might realistically expect. Gross benefit (GB) was derived by multiplying the adjusted grain yield by the farm gate price, calculated as GB = AGY × P. The total variable costs (TVC) encompassed all operational costs, including seed and labor for row-making and weeding. The net benefit (NB) was determined by subtracting the total variable costs from the gross benefit, expressed as NB = (GY × P) - TVC. This formula highlights the relationship between yield, market price, and operational costs. Following this, the dominance analysis procedure, as per CIMMYT guidelines, was employed to identify potentially profitable treatments, categorizing them into dominated (D) and non-dominated (ND) groups.

**RESULT AND DISCUSSION**

The results of ANOVA on sunflower spacing combined of six environments in 2023 and 2024 on growth parameters and yield and yield related parameters are presented in Table 1. The result of ANOVA showed environment (years by locations) highly significantly affected all recorded parameters and the combined main effects of inter-row and intra-row spacing also highly significantly affected all recorded parameters listed in Table 1. However, their interaction significantly affected only head weight (HW) and Grain yield. The combined interaction effect of environment and inter-row spacing highly significantly affected on head weight (HW) and significantly affected on thousand seeds weight (THSW) and Grain yield. The combined interaction effect of environment and intra-row spacing significantly affected on head weight (HW) and number of seeds per head (NSPH) and highly significantly affected on Grain yield. The combined interaction effect of environment, inter-row and intra-row spacing had no significantly affected all recorded parameters listed in Table 1.

Table 1. ANOVA table of sunflower spacing combined of six environments in 2023 and 2024

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| SOV | DoF | DF | DM | PH(cm) | HD(cm) | HW(gm) | NSPH | THSW(gm) | YIELD(kgh-1) |
| Env | 5 | 125.1\*\* | 435\*\* | 866.1\*\* | 37.3\*\* | 61627.7\*\* | 412881\*\* | 656.9\*\* | 42967\*\* |
| RS | 3 | 289.1\*\* | 504.2\*\* | 5355.5\*\* | 146.8\*\* | 31271.3\*\* | 429389\*\* | 1558.7\*\* | 14361\*\* |
| PS | 2 | 223.7\*\* | 296.5\*\* | 1385.7\*\* | 305.8\*\* | 17855.1\*\* | 768504\*\* | 822.3\*\* | 3195\*\* |
| RS\*PS | 6 | 4.7ns | 1.2ns | 20.7ns | 2.6ns | 375.1\*\* | 4003ns | 0.82ns | 183507\* |
| Env\*Rs | 15 | 2.8ns | 3.4ns | 46.9ns | 0.61ns | 762.6\*\* | 5020ns | 23.7\* | 179534\* |
| Env\*Ps | 10 | 5.9ns | 14.9ns | 55.2ns | 7.9ns | 583.3\* | 27658\* | 7.1ns | 34492\*\* |
| Env\*Rs\*Ps | 30 | 0.7ns | 4.2ns | 11.4ns | 0.72ns | 66.4ns | 1206ns | 9.7ns | 61766ns |

NB; DoF= Degree of freedom; DF=Days to flowering; MD=Days to Maturity; PH=Plant height; HD=head diameter, HW= Head weight; NSPH=Number of seed per head; THSW= Thousand seed weight and Yield= yield per hectare

**Effect of inter and intra row spacing of on growth parameters yield and yield components sunflower**

**Days to 50% flowering and maturity:** The combined main effect of inter and intra row spacing were highly significant (*P<0.01*) effect on days to 50% flowering and to maturity on both locations. However, non-significantly (P>0.05) effected by the interaction effect of inter and intra row spacing (Table 1).The maximum number of days to 50% flowering (68) and (67) were recorded from 115cm inter and 40cm intra-row spacing, respectively while the minimum number of days to 50% flowering (62) and (63) were recorded from 55cm inter and 20cm intra-row spacing, respectively. This showed that in narrower inter and intra row spacing competition for nutrients, moisture and space accelerated days flowering. This result is in line with Demir *(2020*) who reported that Narrowing inter and intra row spacing increased plant height, caused early flowering and harvest maturity.

The longest number of days maturity (108) and (106) were recorded from 115cm inter and 40cm intra-row spacing, respectively while the shortest number of days to maturity (101) and (102) were recorded from 55cm inter and 20cm intra-row spacing, respectively( Table 2). This showed that in narrower inter and intra row spacing competition for nutrients, moisture and space, accelerated crop maturity. This result is in line with Demir *(2020*) who reported that narrowing inter and intra row spacing increased plant height, caused early flowering and harvest maturity.

**Plant height (PH):** *-* the main effect of inter and intra row spacing showed highly significant (P<0.01) effect on plant height in combined over locations. However, it was non-significant (P>0.05) to the interaction effect of inter and intra row spacing (Table 1). The tallest (191.5 cm) and (182.8 cm) plant heights were recorded from the plant growth with 55cm inter and 20cm intra-row spacing, respectively. The shortest (167.8cm) and (174.4cm) plant heights were recorded 115cm inter and 40cm intra-row spacing, respectively (Table-2). This might be as the fact that the spacing between plants decreased the interplant competition for light and nutrients increased while sparsely populated plants intercepted sufficient sunlight that enhanced the lateral growth. This result is in line with Awais *et al.* (2015), who reported that Plant height increased under higher plant density per unit area due to the competition of plants for the light.

**Head diameter (HD)*:*** *-*head diameter significantly affected by the main effect of spacing. The largest head diameter (18.3cm) and (18.6cm) were recorded from 115cm inter and 40cm intra-row spacing, respectively. The lowest head diameter (14.4cm) and (14.5cm) were recorded from the plant growth with 55cm inter and 20cm intra-row spacing, respectively (Table 2). Increased plant spacing increased the head diameter of the sunflower and the smaller head diameter of closer spacing may be due to the competition of plants for nutrients, moisture, light and carbohydrates. This result is in agreement with Babkir A Ibrahim et al., (2023) *who reported* that increasing in plant densities led to decreased head diameter. The result is also in line with El Naim and Ahmed (2010) who reported that increasing in plant densities led to decreased head diameter

**Number of seeds per head (NSPH)*:*** *-* The combined analysis of variance indicated that the average number of seeds per head had highly significantly (P<0.01) influenced by main effect of inter and intra row spacing but not for the interaction effects (Table 1). The highest (1068) and (1049) seeds per head were recorded from the plant growth with 115cm inter and 40cm intra-row spacing, respectively (Table 2).The lowest (854) and (848) the average number of seeds per head were recorded from the plant growth with 55cm inter and 20cm intra-row spacing, respectively. This was due to larger heads at wider spacing. This result is in agreement with Hamed Modanlo *et al.,* 2021, plant height, head diameter, 100-grain weight and grain yield/plant all decreased with increasing plant density

**Thousand seeds weight (THSW)*: -*** The combined main effects of inter - and intra- row spacing of sunflower had highly significant (P<0.01) effect on thousand seed weight, whereas their interaction effect had non-significant (P>0.05) effect (Table 1). The heaviest (62.3gm) and (58.8gm) thousand seed weight were recorded from 115cm inter and 40cm intra-row spacing, respectively and the lowest (49.3cm) and (52cm) thousand seed weight were recorded from 55cm inter and 20cm intra-row spacing, respectively (Table 2). Decreasing inter- and intra- row spacing might have increased number of plants and increased inter specific competition which eventually caused reduction in weight of seeds. This finding aligns with Pereira and Hall (2019), who demonstrated that increasing plant density per unit area results in a reduction of both seed number per head and thousand-seed weight.

Table 2. Main effect of inter and intra row spacing on growth parameters and yield related parameters in combined over location

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Treatment | DF | DM | PH(cm) | HD(cm) | NSPH | THSW (gm) |
| Row spacing(cm) | | | | | | |
| 55 | 62d | 101d | 191.5a | 14.4d | 853.5d | 49.3d |
| 75 | 64c | 103c | 181.9b | 16.2c | 943.8c | 54.4c |
| 95 | 66b | 105b | 175.9c | 17b | 986.7b | 56.7b |
| 115 | 68a | 108a | 167.8d | 18.3a | 1067.6a | 62.3a |
| LSD (5%) | 0.98 | 1.2 | 3.64 | 0.52 | 32.2 | 1.2 |
| Plant spacing(cm) | | | | | | |
| 20 | 63c | 102c | 182.8a | 14.5c | 848.2c | 52c |
| 30 | 65b | 104b | 180.7a | 16.2b | 991.8b | 56.2b |
| 40 | 67a | 106a | 174.4b | 18.6a | 1048.6a | 58.8a |
| LSD (5%) | 0.85 | 1.07 | 3.2 | 0.44 | 27.9 | 1.03 |
| Mean | 64.7 | 104.2 | 179.3 | 16.5 | 962.9 | 55.7 |
| CV (%) | 3.98 | 3.12 | 5.34 | 8.22 | 8.78 | 5.6 |

DF=Days to flowering; DM=Days to Maturity; PH=Plant height; HD=head diameter; NSPH=Number of seed per head; THSW= Thousand seed weight

***Head weight (HW):-*** The combined main and interaction effect of inter and intra row spacing’s were highly significant (P<0.01) effect on head weight (Table 1). The highest (216.2) head weight (gm.) were recorded from the plant growth with 115cm inter by 40cm intra-row spacing. The lowest (132.5) head weight (gm.) were recorded from the plant growth with 55cm inter by 20cm intra-row spacing (Table 3). The smaller head weight of closer spacing may be due to the competition of plants for nutrients, moisture, light and carbohydrates. This result is in line with Demir *(2020*) who reported that the plant yield was increased by increased inter and intra row spacing in which the number of plants per unit area decreased. This result is also in agreement with Mamoun and Ekhlas (2023) *who reported* that the highest head yield(g) was recorded the widest inter- and intra-row spacing and the lowest head yield(g) was recorded the narrowest inter- and intra-row spacing.

***Grain yield: -*** The combined analysis of variance showed that the interaction effect of inter - and intra- row spacing of sunflower had significant effect (P<0.05) on grain yield (Table 1). The highest grain yield (2375.2 kg/ha) were recorded from 75cm inter by 30cm intra-row spacing. The lowest grain yield (1704.3 kg/ha) were recorded from 115cm inter by 40cm intra-row spacing (Table 3). The possible reason could be that, when inter and intra row spacing decreased, the number of plants per unit area increased, resulting in higher grain yield per hectare. However, this could be up to certain level of inter row spacing. The lowest grain yields from the widest inter row and intra row spacing might be due to the total yield per unit area depends not only on the performance of individual plant but also on the number of plants per unit area. This finding aligns with Mamoun and Ekhlas (2023), who demonstrated that a narrower combination of intra-row and inter-row spacing significantly enhances seed yield across both growing seasons, while wider spacing results in lower yields.

Table 3. Interaction effect of inter and intra row spacing of on growth parameters and yield related parameters are presented combined over six environment in 2023 and 2024 at Metema and Merab-Armachiho.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Treatment | HW(gm.) | | | Yield (kgh-1) | | |
| Plant spacing | | | | | |
| Row spacing | 20 | 30 | 40 | 20 | 30 | 40 |
| 55 | 132.5g | 140.7f | 154.9e | 1961.5bcd | 1945.3bcd | 1927.6bcd |
| 75 | 155.9e | 178.9d | 189.2c | 2059.3b | 2375.2a | 1975.1bc |
| 95 | 157.1e | 183.2cd | 197.1b | 1879.1cde | 1834.2cdef | 1826.4cdef |
| 115 | 186.3c | 200.7b | 216.2a | 1754.5ef | 1809.1def | 1704.3f |
| MEAN | 174.4 | | | 1921 | | |
| LSD (5%) | 6.7 | | | 152.5 | | |
| CV (%) | 5.8 | | | 12.05 | | |

HW= Head weight

**Partial budget analysis: -**The cost-benefit analysis revealed that the highest net benefit of 89671.4 Eth-Birr with MRR% of 1178.4 was obtained from interaction of 75 cm inter and 30 cm intra-row spacing. The lowest net benefit, 60131 Eth-Birr, was obtained from the interaction of 55 cm inter and 40 cm intra- row spacing. Moreover, the dominance analysis in Table 4 showed that 7 treatments were dominated and the reset 5 treatments were not dominated. Dominated treatments were not used for comparison of marginal analysis. Calculation of net benefit accounts for costs that vary. Therefore, planting sunflower within 75 cm inters- and 30 cm intra-row spacing is economically advisable for farmers in the study area for better sunflower production; because the highest net benefit and the marginal rate of return were above the minimum level (100%). Thus, 1178.4 % MRR indicates that by investing 1 Birr a farmer can get 117.8 Eth-birr (Table 4).

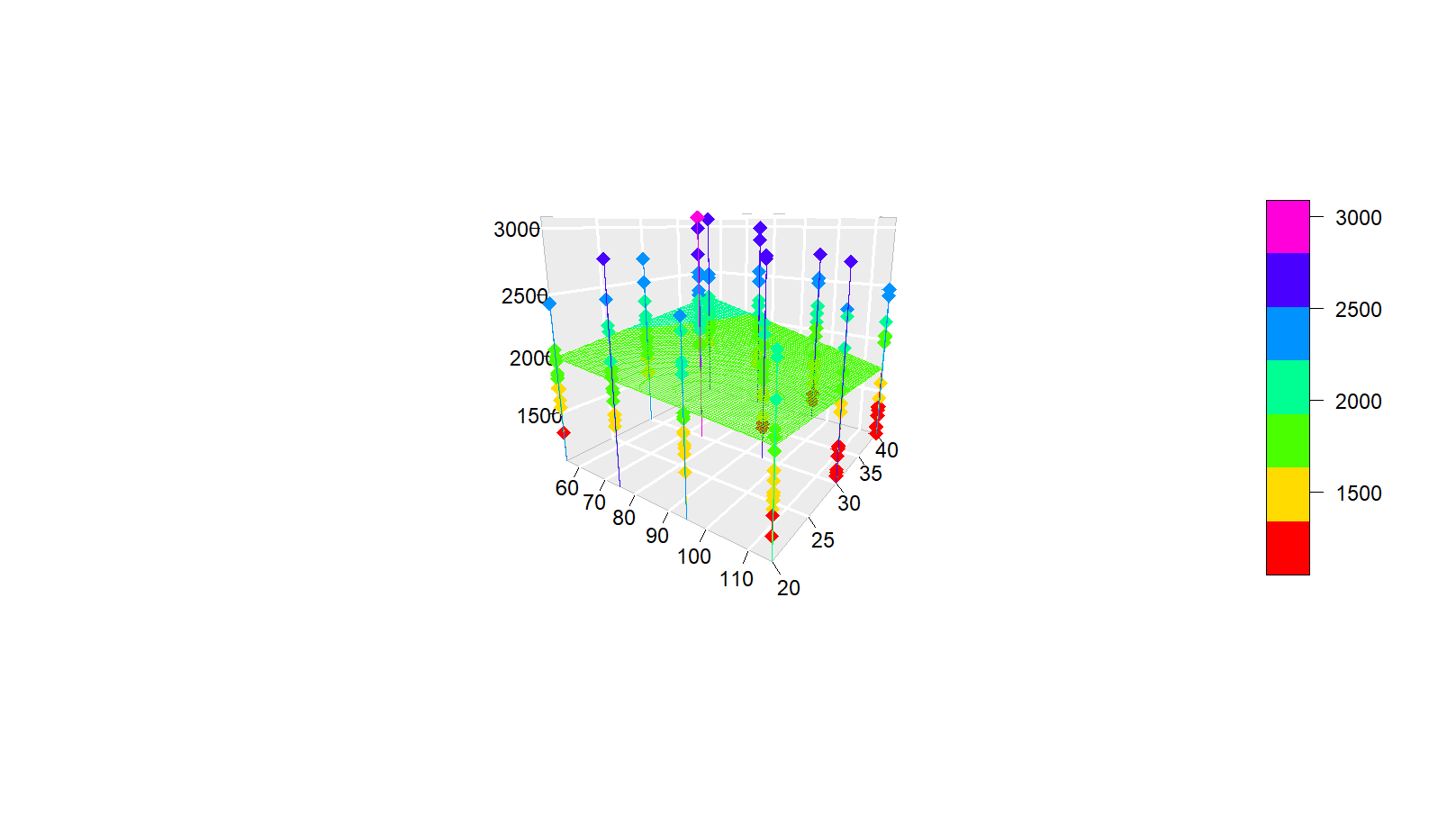
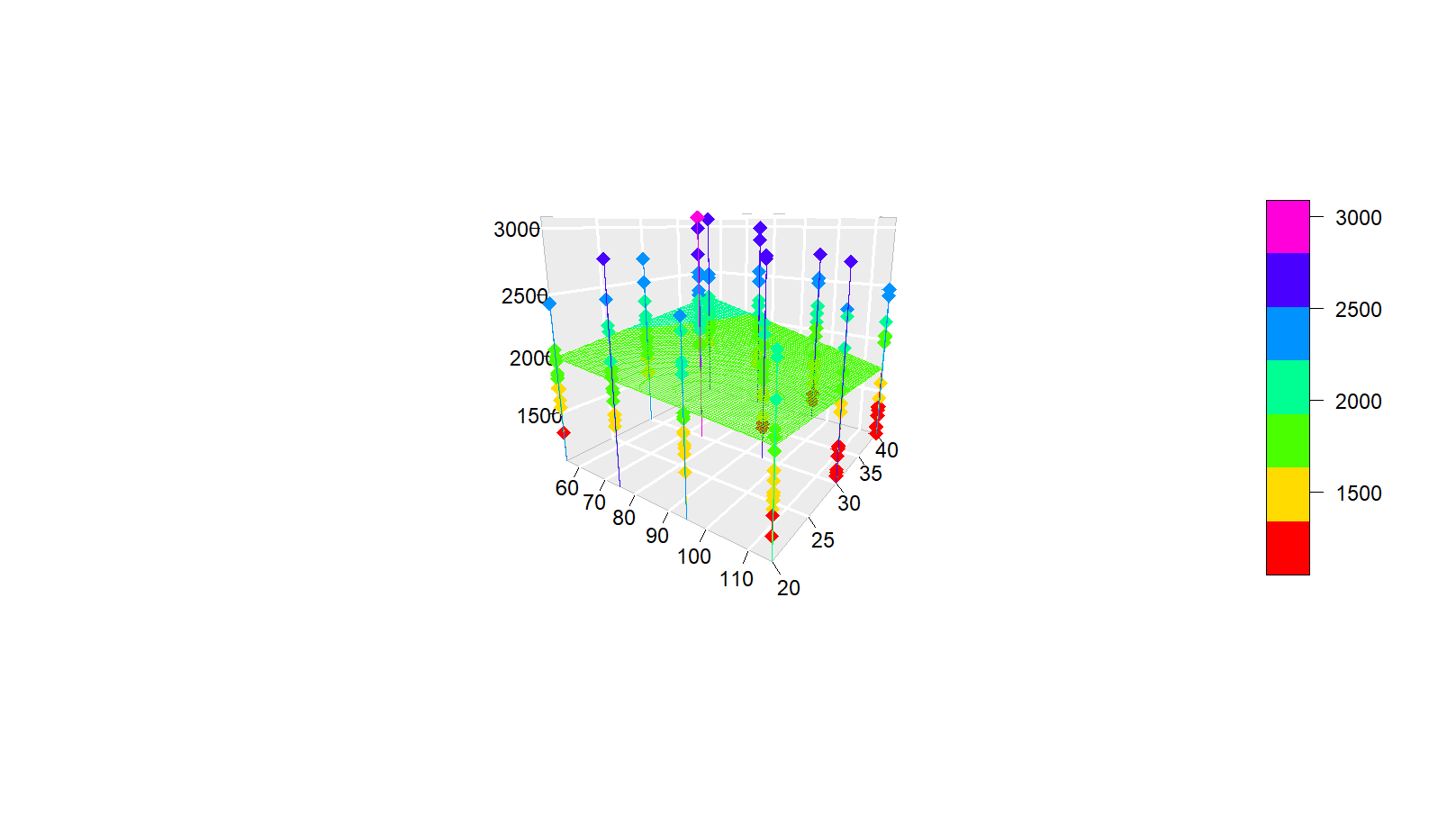
Table 4. Partial budget analysis for inter and intra row spacing effect on seed yield of sunflower

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| RS (cm) | PS (cm) | GY (kg h-1) | Adj .GY (kgh-1) | GB (Et. Birr) | TVC (Et. Birr) | NB (Et. Birr) | D | MRR (%) |
| 115 | 20 | 1754.5 | 1579.05 | 94743 | 24689.7 | 70053.3 |  |  |
| 115 | 40 | 1704.3 | 1533.87 | 92032.2 | 25849.7 | 66182.5 | D |  |
| 115 | 30 | 1809.1 | 1628.19 | 97691.4 | 27387.7 | 70303.7 |  | 267.9 |
| 95 | 20 | 1879.1 | 1691.19 | 101471.4 | 29693.1 | 71778.3 |  | 63.9 |
| 95 | 40 | 1826.4 | 1643.76 | 98625.6 | 32003.1 | 66622.5 | D |  |
| 95 | 30 | 1834.2 | 1650.78 | 99046.8 | 32183.1 | 66863.7 |  | 134 |
| 75 | 20 | 2059.3 | 1853.37 | 111202.2 | 34419.4 | 76782.8 |  | 443.5 |
| 75 | 40 | 1975.1 | 1777.59 | 106655.4 | 36899.4 | 69756 | D |  |
| 75 | 30 | 2375.2 | 2137.68 | 128260.8 | 38589.4 | 89671.4 |  | 1178.4 |
| 55 | 20 | 1961.5 | 1765.35 | 105921 | 39973.4 | 65947.6 | D |  |
| 55 | 30 | 1945.3 | 1750.77 | 105046.2 | 41949.4 | 63096.8 | D |  |
| 55 | 40 | 1927.6 | 1734.84 | 104090.4 | 43959.4 | 60131 | D |  |

*Price Birr/kg: sunflower=60EBirr seed cost of sunflower=90Ebirr Louver cost=400EBirr,RS=Row spacing(inter row spacing).PS=Plant spacing(intra row spacing) GY=Grain Yield, Adj.GY=Adjusted Grain Yield (10%),GB=Gross Benefit, TVC= Total Variable Cost, NB= Net Benefit, D= Dominance Analysis, MRR= Marginal Rate of Return*

**THE SCATTER PLOT WITH REGRESSION PLANE**

Regression analysis revealed that 78% (R2 = 0.78) of the total variation of grain yield of sun flower was significantly explained by regression equation. The scatter plot with regression plane showed the highest grain yield (2375.2kg/ha) was obtained with the interaction effect of 75cm inter and 30cm intra row spacing Therefore, the inter row spacing 75cm with intra row spacing 30 cm can tentatively be recommended to for sunflower growers in the low lands of Gondar and similar agro ecology

Z=-5.3X + 3.1Y + 2298.1

R2=0.78

P Value

Intercept <2e-16\*\*\*

X (row spacing) 0.000199\*\*\*

Y (plant spacing) 0.4222476

Plant spacing

Row spacing

Yield

Fig. 2. Grain yield response of sunflower to planting different inter-and intra-row spacing

**CONCLUSION AND RECOMMENDATION**

In conclusion, the study demonstrated a significant impact of inter- and intra-row spacing on various parameters of sunflower cultivation. The optimal combination of 75 cm inter-row spacing and 30 cm intra-row spacing yielded the highest grain production of 2375.2 kg ha-1 and a remarkable net benefit of 89671.4 Eth-Birr, underscored by a marginal rate of return of 1178.4%. Based on these findings, it is recommended that sunflower growers in the lowlands of Gondar and similar agro-ecological zones adopt this spacing configuration to maximize yield and profitability. Future research could explore the long-term effects of these spacing strategies on soil health and sustainability.

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**REFERENCE**

Agegnehu Shibabaw, Bitwoded Derebe, Nigatu Gebrie, Umer Beshir, Wudu Getahun and Alemayehu Assefa. (2023). Effects of fertilizer rate and spacing on growth and seed yield of sunflower (*Helianthus annuus* L.) in northwestern Amhara, Ethiopia. Blue Nile Journal of Agriculture Research (BNJAR), 3(2), 43-53.

Ahmad, M., Khaliq, A., Ahmad, R., & Ranjha, A. M. (2010). Allometery and productivity of autumn planted maize hybrids under narrow row spacing. *Int. J. Agric. Biol*, *12*(5), 661-667.

Alemaw Getinet, and Fekadu Gurmu. (2023). Towards edible oil self-sufficiency in Ethiopia: Lessons and prospects. *Cogent Food & Agriculture*, *9*(1), 2198742.

Awais, M., A. Wajid, A. Ahmad, M. Saleem, M. Bashir, U. Saeed, J. Hussain and M.H. Habib-ur-Rahman. (2015). Nitrogen fertilization and narrow plant spacing stimulates sunflower productivity. *Turkish J. Field Crops* 20(1):99-108.

Babkir A Ibrahim1, Entisar M. Eldey1, Adam A. Ishag2 & Ahmed M, (2023). El Naim, Response of Sunflower (*Helianthus Annuus* L) to Plant Spacing. *Paradigm Academic Press Innovation in Science and Technology* 2(2):32-37.

Baleseng, L., Madibela, O., Tsopito, C., Mareko, M., Boitumelo, W., & Letso, M. (2023). Morula Kernel Cake (Sclerocarya birrea) as a Protein Source in Diets of Finishing Tswana Lambs: Effects on Nutrient Digestibility, Growth, Meat Quality, and Gross Margin. *Animals*, *13*(8), 1-15.

Beg, A., S. Pourdad, and S. Alipour. (2007). Row and plant spacing effects on agronomic performance of sunflower in warm and semi-cold areas of iran. Helia 30(47):99-104.

Central Statistical Agency (CSA) (2021/2022). Agricultural sample survey report on area and production of crops private peasant holdings, meher season. P 19. April 2022 Volume I, Statistical Bulletin No. 586, Addis Ababa, Ethiopia.

Crnobarac, J., Dušanić, N., Balalić, I., Marinković, B., Latković, D., & Jaćimović, G. (2012). Long-term influence of cultural practices on sunflower yields in commercial production in Serbia. In *Program and Abstracts of 18th Intern. Sunfl. Conf., Mar del Plata, Argentina* 2(1): 183-184).

Damodaram, T. and Hegde, D.M., 2010. Oilseeds situation, a statistical compendium, Directorate of Oilseed Research Hydrabad.

Ahmed, M. F. E. M. (2010). Effect of Irrigation Intervals and Inter-row Spacing on the Vegetative Growth Characteristics in Sunflower (Helianthus annuus L) hybrids in Shambat Soil. *Journal of Applied Science Research,* 6(9), 1440-1445.

FAO. (2021). Food and agriculture organization of the United Nations—FAO. In *The Europa directory of international organizations 2021* (pp. 297-305). Routledge..

Hamed Modanlo, Mehdi Baghi, Abbas Ghanbari Malidarreh, (2021). Sunflower (*Helianthus annuus* L.) grain yield affected by fertilizer and plant density. *Central Asian Journal of Plant Science Innovation* **1**(2): 102–108.

Ion, V., G. Dicu, A. G. Basa, M. Dumbrava, G. Temocico, L. I. Epure, and D. State. (2015). Sunflower yield and yield components under different sowing conditions. Agriculture and Agricultural Science Procedia 6(2):44-51.

Ismail Demir,(2020). Inter and intra row competition effects on growth and yield Components of sunflower (*helianthus annuus* l*.*) Under rain fed Conditions. *The Journal of Animal & Plant Sciences*, 30(1): 147-153.

Kabacoff, R. (2022). *R in action: data analysis and graphics with R and Tidyverse*. Simon and Schuster.

Mamoun & Ekhlas, (2023). Effect of intra and inter-row spacing on yield and yield components of sunflower (Helianthus annuus L.) under zero tillage. *Humanities and Natural Sciences Journal,* 4(1): 184-199.

Pereira, M.L. and A. Hall. 2019. Sunflower oil yield responses to plant population and row spacing: Vegetative and reproductive plasticity. Field Crops Res. 230(1):17-30.

Ramos, N. P., Pires, A. M. M., Buschinelli, C. C. A., Vieira, H. B., Castro, C., & Rodrigues, G. S. (2014). Environmental issues in the sunflower crop of Midwestern Brazil: diversification and complementarities in the biodiesel chain. Sunflowers: growth and development, environmental influences and pests/diseases. New York (USA): Nova Science Pubs, 281-296.

United States Department of Agriculture (2021). Ethiopia Oilseeds Report Annual Oilseeds and Products. Ethiopia:Addis Ababa. *Global Agricultural Information Network:* March 24, 2021 Report Number: ET2021-0006.

Urugo, M. M., Teka, T. A., Teshome, P. G., & Tringo, T. T. (2021). Palm oil processing and controversies over its health effect: overview of positive and negative consequences. *Journal of oleo science*, *70*(12), 1693-1706.

Victorița and Viorel, (2022)**.** Sunflower Grain Yield at Different Conditions of Row Spacing and Plant Density*. Scientific Papers. Series A. Agronomy* 115(2): 395-402.