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# Influence of plant population density on growth and yield of Stevia (*Stevia rebaudiana Bertoni* L.) at Wondo Genet South Ethiopia

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**An experiment was conducted at Wondo Genet Agricultural Research Center in the production season of 2013/14 and 2014/15 with the objective of identifying the best combination of intra and inter-row spacing for optimum plant population density of stevia. The experiment was conducted using five intra-row spacing (20cm, 25cm, 30cm, 35cm, and 40cm) and three inter-row spacing (40cm, 50cm and 60cm) with a total treatment combination of fifteen that were laid out in factorial RCBD design with three replications. In 2013/14 cropping season the maximum fresh leaf weight (19467kg ha$^{-1}$), fresh aboveground biomass (25002kg ha$^{-1}$) and dry leaf weigh (7834kg ha$^{-1}$) were obtained from the combined pacing of 20cm intra-row and 40cm inter-row spacing. In 2014/15 cropping season, the maximum fresh leaf weight (16470.1 kg ha-1) and (14433.9kg ha-1), fresh aboveground biomass (27547kg ha$^{-1}$) and (23619.8kg ha$^{-1}$) and dry leaf weight (4773.7 kg ha$^{-1}$) and (4314.0 kg ha$^{-1}$) were obtained from 20cm intra-row and 40cm inter-row spacing respectively. Although the study showed that the highest Stevia herbage yield per unit area was recorded from the combined spacing of 20cm intra-row and 40cm inter-row spacing, considering the difficult condition, we met during weeding and watering, we, therefore; suggest that the best combined intra-row and inter-row spacing for Stevia is 25cm x 40cm to attain maximum yield under appropriate management conditions at Wondo genet and similar locations.**

**Keywords:** Stevia, Inter-row, Intra- row, Spacing, Plant population.

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## INTRODUCTION

Stevia (Stevia rebaudiana L. Bertoni) is a perennial herb that belongs to the family Asteraceae (Ahmed *et al*., 2007; Ojha *et al*., 2010). It is native to South and Central America (Debnath, 2008; Jackson *et al*., 2009; Robinson and King, 1977; Sumon *et al*., 2008). The first commercial cultivation of stevia was started in Paraguay around 1964 (Katayama *et al*., 1976). Currently it is cultivated in Japan, Taiwan, Philippines, Hawaii, Malaysia and overall South America for food and pharmaceutical products (Ahmed *et al*., 2007; Debnath, 2008; Sumon *et al*., 2008). In Ethiopia, it can be cultivated from mid highland to highland parts of the country. However, it cannot be recommended in saline soil for its cultivation. It can grow well between 1600 and 2700 m from mean sea level where the rainfall averages about 800-1700 mm annually. The leaves of Stevia are the source of steviol glycosides, stevioside and rebaudioside, which estimated to be 300 times sweeter than sugar, but also have no effect on blood sugar, so it is helpful for hypoglycaemia and type 2 diabetes (Ramesh *et al*., 2006; Soejorto, 2002).

According to Serio (2010), one planted hectare can produce between 1000 and 1200 kg of dried leaves that contain 60–70 kg stevioside, which is a low yield compared to sugar cane or sugar beet. However, 70 kg stevioside, which is 300 times sweeter than saccharose, is equivalent to a yield of 21,000 kg sugar per hectare. Agricultural factors such as spacing have critical effects on quantitative and qualitative characteristics of plants (Naghdi badi *et al*., 2004). Leaf yield increased with increasing density up to 83000 and 111000 plants/ha of Stevia for the first years of production (Madan *et al*., 2010). The optimum per acre plant population is pre-requisite for higher yield of Stevia like other plants. It enables the plant to utilize land, light and other input resources uniformly and efficiently. Increasing plant population per unit area beyond a certain limit result in competition among the plants for sunlight, nutrients, moisture etc. and may cause severe lodging. So it is imperative to develop such a spacing pattern which may help avoiding excessive crowding and thereby enabling the Stevia plant to utilize these resources more effectively and efficiently towards increased production. Plant density is one of the most important cultural practices, determining herbage yield, as well as other important agronomic attributes of this crop (Taleie *et al*., 2012). Linear increase in biomass yield has been reported with increase in plant density until other production factors become limiting (Norsworthy and Emerson, 2005).

The effect of plant spacing on growth, and biomass yield of Stevia has not been intensively investigated. Stevia in Ethiopia being a new medicinal plant, most of the farmers and large scale producers are not aware of its basic agronomy and growing requirements. Keeping in view the potential of Stevia, the present study was planned with the objective to determine intra-row and inter-row spacing of optimum plant population density for obtaining maximum biomass production of Stevia.

## MATERIAL AND METHODS

The research was conducted at Wondo Genet Agricultural Research Center's fields, in Southern Ethiopia during 2013/14 and 2014/15 growing seasons to evaluate the influence of plant population density on growth and biomass yield of Stevia (S*tevia rebaudiana bertoni L.)*. Wondo Genet is located at $7^0$192 N latitude and $38^0$ 382 E longitude with an altitude of 1780m. a. s. l. The site receives a mean annual rainfall of 1000mm with minimum and maximum temperature of $10^0$C and $30^0$C, respectively. The soil is a sandy clay loam with an average pH of 7.2. The experiment was conducted using five intra-row spacing (20cm, 25cm, 30cm, 35cm, and 40cm) and three inter-row spacing (40cm, 50cm and 60cm) with a total treatment combination of fifteen that were laid out in factorial RCBD design with three replications.

For seedling preparation, soft stem cutting of 15 cm length was taken from a one year old disease free Stevia mother plants maintained at Wondo Genet Agricultural Research Center botanical garden. Seedlings were raised in the nursery for three months in polyethylene pots. Transplanting was done in October, 2013, First cycle harvesting was done three months after transplanting, and second cycle harvestings and third cycle harvestings were done at three month intervals for two consecutive years.

Data on plant height, number of branches per plant, were recorded from each harvesting cycle and the average value of each year was used for analysis. In addition to this, fresh leaf weight in gram plant$^{-1}$, fresh aboveground biomass, fresh leaf weight, and dry leaf weight in kg ha$^{-1}$ were taken three times in each year and the values summed up and analysed.

The collected data were statistically analysed using SAS computer software version 9.0 English and differences between means were assessed using the least significant difference (LSD) test at $P < 0.05$.

## RESULT AND DISCUSSION

### Plant height

Plant height was significantly ($p<0.05$) affected by the main effect of inter-row spacing in 2013/14 cropping season and by pooled mean, however, intra-row spacing and its interaction with inter-row was not significant (Table 1). In 2014/15 cropping season plant height was not affected by the main effect of intra- row and inter-row spacing and by their interaction (Table 2). During 2013/14 maximum plant height (46.9cm) and (47.4cm) were recorded from intra and inter-row spacing of 20cm and 40cm respectively (Table 3). Plant height was increased at closer spacing. This finding was consistent with the data reported by Taleie *et al*. (2012) who observed that taller Stevia plants were achieved by the closer spacing (50×20 cm). In contrast, Lee *et al.* (1980) had reported that plant height was unaffected by plant density of 50-70cm inter-row and 10-30cm intra-row spacing. An increase in plant height with decreased plant spacing was also reported by Khorshidi *et al*. (2009) in Fennel. Such an increase in plant height with increased plant density may be explained by increased activity of stem growth hormone for plant sunlight competition.

Table 1: Mean square analyses of variance of growth and yield parameters of stevia as affected by intra-row and inter row spacing in 2013/14 cropping season

| Source of variation | DF | PH | NBPP | $FLWgp^{-1}$ | FLW kg $ha^{-1}$ | FAGB kg $ha^{-1}$ | DLW kg $ha^{-1}$ |
|---|---|---|---|---|---|---|---|
| Replication | 2 | 22.04 | 67.3 | 2103.9 | 9834383.2 | 42727622.7 | 3439278.4 |
| Intra- row | 4 | 9.48ns | 178.4* | 4496.8** | 41272705.4** | 74207748.1** | 7084573.8** |
| Inter row | 2 | 26.45* | 202.2* | 5628.1** | 28880392.4** | 30714598.5* | 3958008.6* |
| Intra x inter | 8 | 1.563ns | 27.01ns | 968.6* | 4586855.7* | 12918906.6* | 993399.82* |
| Error | 16 | 3.43 | 14.80 | 220.1 | 1236442.0 | 3674206.9 | 343111.74 |
| CV% | | 4.04 | 6.31 | 7.75 | 8.3 | 8.81 | 11.5 |

*Significant at p<0.05, ** highly significant at p<0.01, ns=Not Significant at p<0.05, Ph = Plant height, in cm NBPP= Number of branch per plant, FLW g p-1=fresh leaf weight gram per plant, FLWPH = fresh leaf weight kg per hectare, FAGBY =Fresh aboveground biomass weight kg per hectare, and DLWY= Dry leaf weight kg per hectare

Table 2: Mean square analyses of variance of growth and yield parameters of Stevia as affected by intra-row and inter row spacing in 2014/15 cropping season

| Source of variation | DF | PH | NBPP | FLWP g $p^{-1}$ | FLW kg $ha^{-1}$ | AGFB kg $ha^{-1}$ | DLW kg $ha^{-1}$ |
|---|---|---|---|---|---|---|---|
| Replication | 2 | 39.225 | 21.52 | 2880.8 | 11390383.7 | 37961710 | 1467591 |
| Intra- row | 4 | 12.0ns | 71.81* | 1097.4* | 70952516 ** | 211829370** | 5425129* |
| Inter- row | 2 | 3.39ns | 25.51ns | 1448.79* | 55381770** | 142377760** | 6171908* |
| Intra x inter-row | 8 | 10.95ns | 41.96ns | 260.13ns | 3609618.8ns | 9703396.7ns | 342678ns |
| Error | 16 | 4.39 | 17.01 | 303 | 1893985.5 | 6178132 | 525204 |
| CV% | | 5.48 | 12.3 | 9.9 | 11.05 | 12.12 | 19.9 |

*Significant at p<0.05, ** highly significant at p<0.01, ns=Not Significant at p<0.05, Ph = Plant height, NBPP= Number of branch per plant, fresh leaf weight gram per plant, FLWPH = fresh leaf weight kg per hectare, FAGBY =Fresh aboveground biomass weight kg per hectare, and DLWY= Dry leaf weight kg per hectare

**Branch Number per plant**

The main effect of intra-row and inter-row spacing had highly significant (P<0.01, Table 1) effect on the number of branches per plant during 2013/14 cropping season and pooled mean. However, their interaction had no significant (P>0.05) effect on the number of branches per plant. Maximum number of branch per plant (65) was recorded at 40cm intra-row spacing. While the lowest number of branches per plant (55) was obtained at closer spacing (20cm) intra-row spacing. For the inter-row spacing the highest number of branches per plant (65) was obtained from 60cm spacing. Whereas the lowest number of branches per plant (57) was obtained at 40cm spacing (Table 3). During 2014/15 cropping season the main effect of intra-row spacing showed significant (P<0.05) difference on the number of branches per plant, while the main effect of the inter-row and its interaction with intra- row was insignificant (Table 2). In 2014/15 the highest number of branch plant $^{-1}$ (37) was recorded from 40cm intra-row spacing and the lowest number of branches per plant (30) was obtained from intra-row spacing of 20cm (Table 3). Number of branches per plant were increased in wider spacing. This finding is

Table: 3 Main effects of intra-row and inter-row spacing on yield and yield components of Stevia for two consecutive cropping seasons (2013/14 to 2014/15).

| Treatments | Plant height (cm) | | | Branch number per plant | | | Fresh leaf weight(g $p^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|
| Intra-row (cm) | 2013/14 | 2014/15 | Pooled mean | 2013/14 | 2014/15 | Pooled mean | 2013/14 | 2014/15 | Pooled mean |
| 20 | 46.9a | 39 | 42.9a | 55d | 30c | 42.4c | 161.3c | 160.1b | 160.70d |
| 25 | 45.9ab | 38 | 41.9ab | 59c | 32bc | 45.2bc | 181.8b | 171.7b | 176.75c |
| 30 | 46.8a | 38 | 42.4ab | 61bc | 33abc | 47.2b | 187.8b | 174.1ab | 180.95bc |
| 35 | 44.5b | 38 | 41.3b | 64ab | 36ab | 50.7a | 208.3a | 176.2ab | 192.25b |
| 40 | 45.2ab | 38 | 41.6b | 65a | 37a | 50.6a | 217.9a | 190.9a | 204.4a |
| LSD5% | 1.8 | Ns | 1.32 | 3.8 | 4.1 | 2.95 | 14.8 | 17.39 | 12.1 |
| Inter-row (cm) | | | | | | | | | |
| 40 | 47.4a | 39 | 43.2a | 57c | 32 | 44.70b | 173.9c | 164b | 168.95c |
| 50 | 44.8b | 38 | 41.4b | 61b | 35 | 47.85a | 189.7b | 176ab | 182.85b |
| 60 | 45.4b | 38 | 41.7b | 65a | 34 | 49.35a | 211.6a | 183a | 197.30a |
| LSD5% | 1.39 | Ns | 1.02 | 2.97 | Ns | 2.28 | 11.48 | 13.4 | 9.41 |
| CV | 7.8 | 8.7 | 4.7 | 6.31 | 12.3 | 9.4 | 7.75 | 9.9 | 10 |

Means followed by the same letter within a column are statistically non-significant at $p \leq 0.05$ probability level; CM =centi meter; CV=Coefficient of Variance; LSD= Least Significant Difference.

consistent with the result of Maheshwar (2005) who reported higher branch number plant$^{-1}$ at the wider spacing than the closest in Stevia. Similarly result was reported by Beemnet *et al*. (2012) on Rose Scented Geranium (*Pelargonium graveolens*), Zewdinesh *et al*. (2011) on Artemisia (*Artemisia annua* L.).

## Fresh leaf weight per plant (g $p^{-1}$)

The main effect of intra-row and inter-row spacing showed a highly significant ($P<0.01$, Table 1) and their interaction had significantly ($P<0.05$, Table 1) affected fresh leaf weight per plant in 2013/14 cropping season and pooled mean.

In 2013/14 cropping season, maximum fresh leaf weight plant$^{-1}$ (246.4g $p^{-1}$) was obtained from the combined spacing of 60cm x 40cm inter-row and intra-row spacing respectively which was statistically similar with fresh leaf weight plant$^{-1}$(227.8 g $p^{-1}$) and (221.8 g $p^{-1}$) recorded from the combined spacing of 60cm x 35cm and 50cm x35cm inter-row and intra-row spacing respectively. Whereas the lowest fresh leaf weight (149.7 g $p^{-1}$) was recorded at the interaction effect of inter-row and intra-row spacing of 40cm and 20cm respectively (Table 5). Fresh leaf weight per plant at wider spacing showed 64.6% increment over the closest spacing during 2013/14. In 2014/15 cropping season the main effect of inter-row and intra row spacing had significantly ($P<0.05$, Table 2) affected fresh leaf weight plant$^{-1}$. However, their interaction had no a significant effect on fresh leaf weight plant$^{-1}$. Maximum fresh leaf weight (183 g $p^{-1}$) and (190 g $p^{-1}$) was obtained from 60cm inter-row and 40cm intra-row spacing respectively. The lowest fresh leaf weight plant $^{-1}$ (164g $p^{-1}$) and (160.1 g$p^{-1}$) was obtained from the spacing of 40cm inter-row and 20cm intra row spacing (Table 3). In agreement with this study, Taleie *et al* (2012) reported maximum fresh leaf weight per plant at wider spacing on Stevia. The finding is also in line with the work of Zewdinesh *et al* (2011) on Artemisia (*Artemisia annua* L.). In increasing plant spacing from 20cm to 40cm and from 40cm to 60cm intra-row and inter-row spacing respectively fresh leaf weight per plant was increased. At wider spacing, there is less inter-row and intra-row plant competition for available resources and the plant have a chance to develop more number of branches and leaf that could be the reason for maximum fresh leaf weight per plant obtained than in closer spacing.

## Fresh leaf weight (Kg ha$^{-1}$)

The analysis of variance showed that the main effect of inter and intra-row spacing showed highly significant (P<0.01) differences in fresh leaf weight (kg ha$^{-1}$) and significantly (P<0.05) influenced by the interaction effect of inter and intra-row spacing in 2013/14 cropping season and polled mean (Table 1).

The highest fresh leaf weight (19,467 kg ha$^{-1}$) was obtained from the combination of 40 x 20 cm spacing, while the lowest (10269 kg ha$^{-1}$) leaf, fresh weight was recorded from the combination of 60 x 40cm inter and intra-row spacing in 2013/14 (Table 5). The next highest fresh leaf weight (15205 kg ha$^{-1}$) was recorded from the combined spacing of 40 x 25cm which was statistically at par with the fresh leaf weight (13609 kg ha$^{-1}$), ( 13669kg ha$^{-1}$) (14974 kg ha$^{-1}$), (14770kg ha$^{-1}$), (13563kg ha$^{-1}$) and (14869kg ha$^{-1}$) obtained from the combination of 40x30cm, 40x40cm, 50x20cm, 50x25cm, 50x30cm and 60x25cm spacing respectively in the first harvesting year (Table 5). In 2013/14 cropping season for the inter-row spacing 40cm, 50cm & 60cm as the intra-row spacing increased from 20cm- 40cm, the leaf fresh weight per hectare was decreased by 29.8%, 51.5% & 47.2% respectively (Table 5). While spacing between plants and rows decreases, fresh leaf yield per hectare was found to be increased. In 2014/15 leaf, fresh weight per hectare was highly significantly (P<0.01, Table 4) influenced by the main effect of inter-row and intra-row spacing. However, interaction of intra and inter-row spacing had no significant difference in fresh leaf weight per hectare.

In 2014/15 cropping season the maximum fresh leaf weight (16470.1 kg ha$^{-1}$) and (14433.9 kg ha$^{-1}$) were recorded from 20cm intra-row and 40cm inter-row spacing. The lowest fresh leaf weight (9720.3 kg ha$^{-1}$) and (10597.6 kg ha$^{-1}$) were obtained from 40cm intra-row and 60cm inter-row spacing (Table 4). The decrease in fresh leaf yield per hectare with increasing plant spacing was reported by Madan *et al*. (2010) in stevia. This finding is also in line with the works of Stevia spacing reported by; Basuki, 1990; Carneiro *et al*., (1992); Murayama *et al*. (1990). The decreased in fresh leaf yield per hectare with increased plant spacing was reported by Taleie *et al*. (2012) in Stevia, Zewdinesh (2010) in Artemisia. Similar finding were also reported by Solomon and Beemnet (2011) for Japanese mint and Beemnet *et al* (2012) on Rose scented geranium. Lower fresh leaf weight per unit area in wider spacing could be due to the accommodation of the least number of plants per unit area.

## Above ground fresh biomass (kg ha$^{-1}$)

Above ground fresh biomass (kg ha$^{-1}$) was highly significantly affected (P<0.01) by the main effect of inter and intra-row spacing in both years and significantly (P<0.05) influenced by their interaction in 2013/14 cropping season and polled mean (Table 1 & 2). Maximum aboveground fresh biomass (25002 kg ha$^{-1}$) was obtained from inter row spacing of 40cm combined with intra row spacing of 20cm which were statistically similar to the value obtained at the combined spacing of 40x25cm, 40x30cm, 40x40cm, 50x20cm, 50x25cm, 50x30cm, 60x20cm and 60x25cm spacing in 2013/14 cropping year (Table 5). The lowest aboveground fresh biomass (15624 kg ha$^{-1}$) was recorded at the combination of 60x40cm inter and intra-row spacing respectively. While the spacing increased from 40x20cm to 60x40cm inter and intra-row spacing fresh aboveground biomass per hectare was decreased by 37.5% in 2013/14 cropping season (Table 5). Maximum aboveground fresh biomass (27547 kg ha$^{-1}$) and (23619.8kgha$^{-1}$) was recorded from 20cm inter-row and 40cm intra-row spacing respectively in 2014/15.

The lowest aboveground fresh biomass (15595kg ha$^{-1}$) and (17460.1kg ha$^{-1}$) was recorded from 40cm intra-row and 60cm inter-row spacing respectively (Table 4). This finding is in agreement with the result of Kumar *et al*. (2014) who reported maximum fresh aboveground biomass yield per hectare at closer spacing than the wider spacing on Stevia. Similarly to the present study, Solomon and Beemnet (2011) reported a decreased trend of fresh above ground biomass yield with increased row spacing from 30 to 60cm for Japanese mint. In addition to this previous research findings conducted by Nigussie *et al*. (2015) on Artemisia, Zewdinesh (2010) on A. annua supports this finding. An increase in fresh aboveground biomass in higher plant population density may be due to the contribution of higher number of plants per unit area which intern gives higher fresh leaf yield ha$^{-1}$.

## Dry leaf weight (kg ha$^{-1}$)

The analysis of variance showed highly significant (P<0.01, Table 1 & 2) differences in dry leaf weight (kg ha$^{-1}$) due to the main effect of inter and intra-row spacing in both years and significantly (P<0.05, Table 5) influenced by the interaction effect of inter and intra-row spacing during 2013/14 cropping season and polled mean. During 2013/14 cropping season maximum dry leaf weight (7834 kg ha$^{-1}$) was registered at the combination of 40x20cm inter-row and intra-row spacing while the lowest (3623 kg ha$^{-1}$) leaf weight was recorded from the combination of 60cm inter and 35cm intra-row spacing (Table 5). The decrease in dry leaf weight in kg

Table 4: Main effect of intra-row and inter-row spacing on yield and yield components of Stevia for two consecutive cropping seasons (2013/14 to 2014/15)

| Treatments | Fresh leaf weight (kg ha$^{-1}$) | | | Above ground fresh biomass (kg ha$^{-1}$) | | | Dry leaf weight (kg ha$^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|
| Intra-row (cm) | 2013/14 | 2014/15 | Pooled mean | 2013/14 | 2014/15 | Pooled mean | 2013/14 | 2014/15 | Pooled mean |
| 20 | 16436.7a | 16470.1a | 16453.4a | 25230.3a | 27547a | 26388.7a | 6392.9a | 4773.7a | 5583.3a |
| 25 | 14632.8b | 14047.7b | 14340.3b | 23937.2a | 23160b | 23548.6b | 5487.1b | 4025.5b | 4756.3b |
| 30 | 12697.5c | 11783.2c | 12240.4c | 21555.5b | 19005c | 20280.3c | 4923.0bc | 3368.4bc | 4145.7c |
| 35 | 12012.3cd | 10230.9d | 11121.6d | 19699.7bc | 17165cd | 18432.4cd | 4530.3cd | 3091.8c | 3811.05d |
| 40 | 11123.0d | 9720.3d | 10421.7d | 18308.5c | 15595d | 16951.8d | 4114.2d | 2862.7c | 3488.45d |
| LSD5% | 1111.2 | 1375.3 | 823.4 | 1915.5 | 2483.9 | 1851.9 | 585.4 | 724.2 | 411.2 |
| Inter-row (cm) | | | | | | | | | |
| 40 | 14892.7a | 14433.9a | 14663.3a | 23168.4a | 23619.8a | 23394.1a | 5633.3a | 4314.0a | 4973.65a |
| 50 | 13082.9b | 12319.8b | 12701.4b | 21763.6ab | 20403.0b | 21083.3b | 5022.7b | 3513.7b | 4268.2b |
| 60 | 12165.8c | 10597.6c | 11381.7c | 20306.6b | 17460.1c | 18883.4c | 4612.5b | 3045.5b | 3829c |
| LSD5% | 860 | 1065.3 | 637.7 | 1483.8 | 1924 | 1434.4 | 453.4 | 560.9 | 318.5 |
| CV | 8.31 | 11.1 | 9.6 | 8.81 | 13.2 | 13.2 | 11.5 | 19.9 | 14.2 |

Means followed by the same letter within a column are statistically non-significant at $p \leq 0.05$ probability level; CM =centi meter; CV=Coefficient of Variance; LSD= Least Significant Difference

**Table: 5** Interaction effect of inter and intra- row spacing on a fresh leaf weight gram per plant, fresh leaf weight kg ha$^{-1}$, fresh aboveground biomass kg ha$^{-1}$ and dry leaf weight kg ha$^{-1}$ of Stevia in 2013/14

| Treatment combination (cm) | Fresh leaf weight per plant (g p$^{-1}$) | Fresh leaf weight (kg ha$^{-1}$) | Aboveground fresh biomass (kg ha$^{-1}$) | Dry leaf weight (kg ha$^{-1}$) |
|---|---|---|---|---|
| | 2013/14 | 2013/14 | 2013/14 | 2013/14 |
| 40x20 | 155.7 hi | 19467a | 25002 a | 7834 a |
| 40x25 | 152.0 i | 15205 b | 24688 a | 5988 b |
| 40x30 | 163.3 ghi | 13609 bc | 22969 ab | 4900 cde |
| 40x35 | 175.2 fghi | 12514 cde | 20568 bc | 4648 def |
| 40x40 | 218.7 bc | 13669 bc | 22615 ab | 4797cdef |
| 50x20 | 149.7i | 14974 b | 24525 a | 5746 bc |
| 50x25 | 184.6 defg | 14770 b | 24406 a | 5396 bcd |
| 50x30 | 203.4 bcde | 13563 bc | 23536 ab | 5262 bcd |
| 50x35 | 221.8 abc | 12676 cd | 20727 bc | 5086 bcd |
| 50x40 | 188.6 defg | 9432 f | 15624 d | 3623 g |
| 60x20 | 178.4 efgh | 14869 b | 26164a | 5600 bcd |
| 60x25 | 208.9 bcd | 13924 bc | 22717 ab | 5078 bcd |
| 60x30 | 196.6 cdef | 10921 def | 18161 cd | 4607defg |
| 60x35 | 227.8 ab | 10847 ef | 17805 cd | 3857 fg |
| 60x40 | 246.4 a | 10269 f | 16686 d | 3922 efg |

**Table 5.** Continuation

| | | | | |
|---|---|---|---|---|
| LSD% | 25.66 | 1778.5 | 3604.7 | 1007.5 |
| CV | 8.0 | 7.9 | 9.9 | 19.9 |

Means followed by the same letter within a column are statistically non-significant at $p \leq 0.05$ probability level; CM =centi meter; CV=Coefficient of Variance; LSD= Least Significant Difference

**Table: 6** Association among growth and yield related characters of stevia tested under varying intra-row and inter-row spacing in 2013/14 cropping season

| Parameters | PH | FLWP | FLW | FAGB | NBPP | DLW |
|---|---|---|---|---|---|---|
| PH(cm) | 1 | | | | | |
| FLWP | 0.70*** | 1 | | | | |
| FLW | 0.77*** | 0.64*** | 1 | | | |
| AGFB | 0.72*** | 0.66*** | 0.88*** | 1 | | |
| NBPP | -0.41*** | 0.03ns | -0.30* | -0.19* | 1 | |
| DLW | 0.64*** | 0.58*** | 0.88*** | 0.87*** | -0.24* | 1 |

*Significant at $p<0.05$, ** highly significant at $p<0.01$, Ph = Plant height, NBPP= Number of branches per plant, fresh leaf weight per plant, FLWPH = fresh Leaf weight per hectare, FAGBY =Fresh aboveground biomass yield and DLWY= dry leaf weight yield .

**Table 7**. Association, among growth and yield related characters of stevia tested under varying intra-row and inter-row spacing in 2014/15 cropping season

| Parameters | PH | NBPP | FLWP | FLW | FAGB | DLW |
|---|---|---|---|---|---|---|
| PH(cm) | 1 | | | | | |
| NBPP | 0.42* | 1 | | | | |
| FLWP | 0.24* | 0.32* | 1 | | | |
| FLW | 0.23* | 0.14ns | 0.31* | 1 | | |
| AGFB | 0.35* | 0.19* | 0.22* | 0.95* | 1 | |
| DLW | 0.02ns | 0.02ns | 0.29* | 0.80* | 0.72* | 1 |

*Significant at $p<0.05$, ** highly significant at $p<0.01$, Ph = Plant height, NBPP= number of branch per plant, leaf fresh weight per plant, LFWPH = leaf fresh weight per hectare, FAGBY =fresh aboveground biomass yield, and DLWY= dry leaf weight yield

ha$^{-1}$ due to increase in inter and intra-row spacing from 40cmx20cm to 60cmx35cm was 53.7% (Table 5). This finding was consistent with the result of Taleie *et al* (2012) who reported higher dry leaf weight kg ha$^{-1}$ at highest plant density for stevia. Kumar *et al* (2014) also reported a higher value of dry leaf weight ha$^{-1}$ with narrow spacing in Stavia. Murayama et al., (1990) also had reported that dry leaf yield was higher in denser planting. A similar pattern was also reported by Solomon and Beemnet (2011) on Japanese mint.

**Correlation analysis, among yield and yield parameters**

The correlation coefficient among different variable revealed that, the stevia yield and yield components were significantly and positively correlated with each other in both years. Fresh leaf weight was positively and significantly correlated with plant height (r=0.77***) & (r=0.23*) and fresh leaf weight per plant (r=0.70***) & (r=0.31*) in 2013/14 and 2014/15 cropping season respectively. Fresh aboveground biomass was positive and very highly significant and significantly correlated with plant height (r=0.72***& r= 0.35*), fresh leaf weight per plant (r=0.66***& r= 0.22*), fresh leaf weight ha$^{-1}$(r=0.88***& r=0.95**) and dry leaf weight kg ha$^{-1}$ (r= 0.87***& r=0.80**) in 2013/14 and in 2014/15 respectively copping season (Table 6 &7).

**CONCLUSION**

The two consecutive study years showed that the highest economic fresh leaf weight (19467kg ha$^{-1}$) and dry leaf weight (7834kg ha$^{-1}$) was recorded from the combined spacing of 20cm intra-row and 40cm inter-row spacing. However; considering the difficult condition, we met during weeding and watering, we, recommend that the best combined intra-row and inter-row spacing for Stevia is 25cm x 40cm rather than 20cm x40cm to attain maximum yield under appropriate management conditions for Wondo genet and similar agro ecology.

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