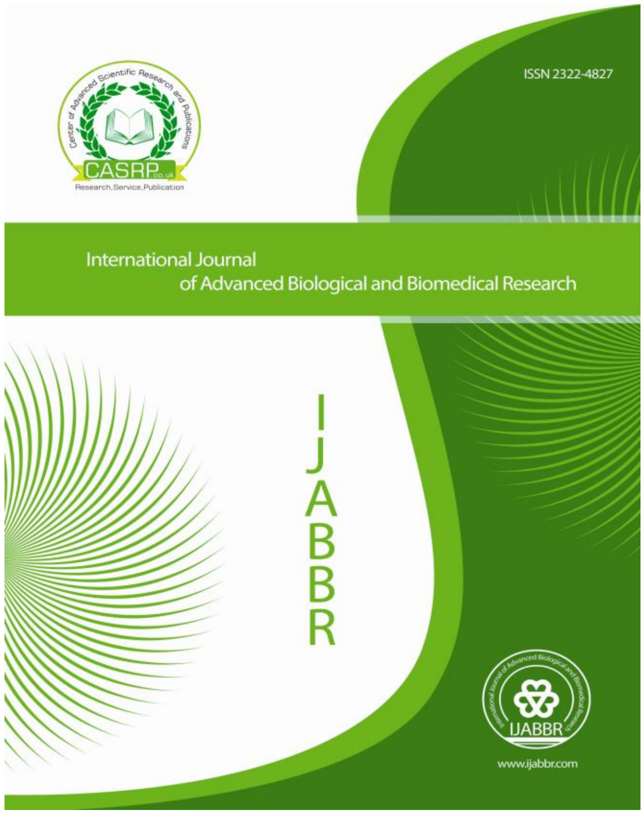
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Influence of inter and intra row spacing on growth and yield of Vernonia (*Vernonia galamensis Cass*.)

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Abstract

Vernonia galamensis Cass is a huge potential industrial crop with very high content of vernolic acid in the seed oil. The experiment was carried out to determine the effect of inter- and intra- row spacing on the yield and yield related traits of *Vernonia galamensis Cas.*The experiment was conducted for two years during 2014-2015 on experimental field of Wondo Genet Agricultural research center, Southern Ethiopia. The factorial combinations of five intra-rows (30, 40, 50, 60 and 70cm) and three inter-row plant spacing (60, 80, 100cm) were laid out in a randomized complete block design with three replications. Data on yield and yield related traits including plant height (cm), number of branch/plant, number of pods /plant, Seed yield kg/ha, oil yield kg/ha, Oleoresin % and 1000 seed weight (gm) were recorded .The combined analysis of the two years trial showed that the interaction effect of Inter and Intra row spacing treatments significantly influenced all parameters measured except thousand seed weight and oil content. Inter and Intra row spacing interaction effect was highly significant (P<0.0001) on number of branches per plant, seed yield and oil yield. The maximum seed yield of 2491.3 kg/ha, Oil yield 932.2kg/ha were obtained from a spacing combination of 60cm intra-row and 60cm inter-rows. Therefore, the inter and intra row spacing combination of 60 x 60cm is a recommendable optimum spacing for Vernonia galamensis (Cass.) production to attain maximum yield under the conditions of Wondo genet and similar locations.

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1. Introduction

Vernonia galamensis, Asteraceae, is a potential new industrial oilseed crop. Recent taxonomic work (Robinson, 1999; Gilbert, 1986) has shown that Vernonia is better referred to the genus Centrapalus Cass., as Centrapalus pauciflorus (Willd.) H. Rob. (Syn.Centrapalus galamensis Cass.). It is a tropical, indeterminate annual plant. It requires a well-drained soil and can grow under low rainfall and marginal conditions and is most suitable for dry land farming (Gilbert 1986, Perdue, 1988, Baye, 2000). Its importance lies in the unique properties of the seed oil, which make it interesting both economically and ecologically. On the other hand, many potentially useful species, such as Vernonia, are represented only by a few accessions. Demissie (1991) has listed the lesser known but potentially valuable crop plants in Ethiopia. He stressed the need for detailed study and proper documentation as a prerequisite for their exploitation.

Vernonia or ironweed is one of 6,500 wild plant species screened by the USDA for production of desirable seed oils (Teynor et al., 1992). This potential oil seed crop is native to eastern Africa. Another vernonia species, V. anthelmintica Willd., was evaluated earlier during the 1950`s for its vernolic (epoxy) acid content. However, consistent problems with seed shattering, disease, and low yield of vernolic acid resulted in an end to further agronomic and breeding studies on this species (Teynor et al., 1992). Hence, Vernonia galamensis has been identified to be a new potential industrial oil seed crop because of its unique properties, which make it economically and ecologically interesting (Perdue et al., 1986). Seeds of Vernonia are rich in Vernolic acid, a naturally epoxidized fatty acid with unique chemical (epoxy) and physical (low viscosity) properties.

Vernonia oil has a potential use in paints industry because of its low viscosity, besides it has a multiple chemical functionality (Perdue et al., 1986). Thompson et al. (1994) reported that no oil crop has been commercialized as a source of natural epoxidized oils. Rather their needs were met with petrochemicals or by expensive chemical modification (epoxidization) of fats and vegetable oils (Croot, 1990), notably soybean and linseed oils. Epoxidation, i. e. the oxidation of double bonds of non-structured fatty substances to form an oxiran or epoxy ring, is regarded as one of the most important addition reaction occurring with fatty acid molecules. This industrial epoxidation process triples or quadruples the price of the original oil to the consumer. Chemically vernonia oil is similar to epoxidized soybean (Glycine max L.) and linseed (Linum ustitatissimum L.) oils. However, soybean oil and linseed oil contains only 50% and 57% of linolenic acid, respectively, as their principal fatty acid, whereas vernolic acid has 78-80% Epoxy fatty acids, commonly known as vernolic acid, is useful raw material for manufacturing paints and coatings with low or no volatile organic compounds (VOC). In this type of application, vernonia oil has a built-in advantage in that it is already epoxidized and vernolic acids are found in abundance in the seed oil, thus could be used as a substitute for currently used epoxy oils (Grinberg et al., 1994).Utilization research for vernonia has shown at least three areas with strong potential markets: (1) as a plasticizer and stabilizer for polyvinyl chloride–a current market, (2) a component in protective coatings, and (3) use in interpenetrating polymer networks with polystyrene to make unique plastics (Teynor et al., 1992).

Since the crop has vast array of industrial applications and huge potential market, by giving emphasis to this crop Ethiopia can gain a great deal of income from this new oil crop. However, most of its appropriate agronomic practices and requirements of the crop were not yet well studied and determined. Hence, realizing the importance of the crop; appropriate cultural practices such as plant spacing for optimum production of the crop have to be known. Therefore, the objective of the experiment is to determine optimum inter- and Intra-row spacing for maximum seed or grain yield, Oil yield and oil/oleoresin content (%) of *Vernonia galamensis.*

2. Materials and methods

This research was conducted during 2014 and 2015 at the wondo genet Agricultural Research Center located at 07° 19.1' N and 38° 30' E ,1780m elevation) under irrigated condition. The site receives mean annual rain fall of 1128 mm with minimum and maximum temperature of 11 and 26°c, respectively. Factorial combinations of five intra-row plant spacing's (30, 40, 50, 60 and 70cm) and 3 inter-row spacing's (60, 70 and 100cm) treatments and were laid out in a randomized complete block design (RCBD) with three replications. Plot size for each treatment was 4.80m x 4m. Seeds of Vernonia were directly sown in the experimental field.

The number of plants per row and the number of rows per plot was determined by intra and inter-row spacing respectively. All required crop management practices were done uniformly to all experimental plots. Harvesting was done when 90% of the seeds became black in color. Data on plant height (cm), number of branch/plant, number of capsule or pods /plant, 50% flowering date, Seed or grain yield kg/ha, oil yield kg/ha, Oleoresin or oil content%, 1000 seed weight (gm).Oleoresin or oil content analysis was done using modified Sox let apparatus. The data sets for each quantitative character were analyzed using the SAS GLM procedure with the SAS software version 9.1.3 followed by mean separation using Fisher's LSD at 5% level of significant.

3. Results and discussion

Mean squares from combined analysis of the two year results showed that the interaction effect of Inter and Intra row spacing treatments influenced all parameters measured except thousand seed weight and oil content (Table1). Inter and Intra row spacing interaction effect was highly significant (P<0.0001) on number of branches per plant, seed yield and oil yield. The influence of Inter and Intra row spacing treatments interaction was significant (P<.001) on plant height and slightly significant (P<0.05) on number of capsules per plant. Thousand seed weight was not influenced neither by main effect nor by interaction effects of planting year, inter and intra-row spacing treatments.

Table 1
Mean squares from combined Analysis of Variance of the effect of intra and inter-row spacing on yield and agronomic performance of Vernonia galamensis (Cass.).

Source of variation	Degree of freedom	PH	NBPP	NCPP	SY (kg/ha)	TSW	OC	OY (kg/ha)
Rep	2	331.6	27.6	120.4	75511.2	0.2ns	4.5	7055.7
Year	1	692.2	9729.4***	6808.6	37231.1	0.2ns	147.5***	63384.6*
Inter-row	4	1343.1***	3002.2***	6321.3***	431356.3***	0.1ns	6.2	61252.7***
Intra-row	2	112.7ns**	9729.4***	2970.6**	2377506.6***	0.2ns	17.8*	326634.2***
Inter*Intra	8	784.1**	467.9***	689.6*	670636.1***	0.2ns	3.8	93636.5***
Inter*Intra*year	14	334.9	184.9**	382.4*	57938.9*	0.2ns	4.8	8891.8*
Error	58	230.6	54.5	272.0	31936.4	0.20	5.4	6576.7
CV		10.3	10.8	11.5	11.9	9.0	6.2	14.6

***= Significant at p < 0.0001; **= p < 0.001; *= p < 0.05 probability level; and ns= non-significant at 0.05 probability level; PH= Plant height (cm), NBPP= Number of branch per plant, NCPP= Number of capsules per plant, SY= Seed Yield (Kg/ha), TSW= Thousand seed weight (g) OC=Oil content (%), OY= Oil yield (Kg/ha).

3.1. Plant height

The combined analysis result revealed that plant height was significantly (p<0.001) influenced by interaction effect of intra-row and inter-row spacing (Table1). The highest plant height (175.3cm) was obtained from closer (30x60cm) spacing (Table 2). The result of this findings is similar with previous findings which indicated that the denser plant population increased the plant height due to competition among plants, as a result plants respond by diverting their resource to vertical growth to capture the available light (Khalil et al., 2010, Yucel, 2013). The direct association of plant height with population density is also reported (Belay and Zewdenesh, 2011), According to Henderson et al. (2000), plant height was significantly influenced by the effect of row spacing, Similarly, Massey (1968) reported that the height of Vernonia plants were significantly greater at narrow intra-row spacing than at wider spacing. High plant density brings out certain modifications in the growth of plants, for example, increase in plant height, reduction in leaf thickness, alteration in leaf orientation, and leaves become erect, narrow and are arranged at longer vertical intervals to intercept more sun light (Singh and Singh, 2002). On other hand, a number of factors such as fertility status of the soil, growth pattern of the crop and cultural practices influence planting density choice (Martin et al., 1976).

Table 2
The interaction effect of intra-row and inter-row spacing on mean performance values of plant height, no-of branches per plant and no-of capsules/pods/ per plant of Venonia galamanisis. Cass.

Intra-row spacing (cm)	Inter-row spacing(cm)								
	Plant height (cm)			No-of branches per plant			No-of capsules/pods/ per plant		
	60 Inter	80 Inter	100 Inter	60 Inter	80 Inter	100 Inter	60 Inter	80 Inter	100 Inter
30	175.3[a]	160.1[ab]	150.6bcd	46.4e	57.2de	58.9bcd	98.5g	128.8ef	131.9def
40	132.2de	146.3cde	150.6bcd	57.2bcd	69.4bcd	71.7b	122.1f	132.9def	133.4def
50	150.5bcd	151.9bc	130.3e	69.4bcd	72.8bcd	74.3bc	135.6cdef	161.2b	147.5bcde
60	153.7bc	137.2cde	149.7bcd	84.9b	69.9bcd	77.9b	156.4bc	148.2bcde	151.7bcd
70	130.1e	146.1cde	143.7cde	78.3 b	78.8b	109.4a	146.8bcde	167.7ab	186.3a
LSD		18.4**			16.8***			22.5**	
CV		10.9			20.8			13.7	

Means followed by the same letters with in columns does not differ significantly at 0.05 probability level.

3.2. Number of branches and capsules /pods/ per plant

Numbers of branches and capsules /pods/ per plant were significantly influenced by main and interaction effects of intra-row spacing and inter-row spacing. The highest number of capsules /pods/ per plant (186.3) and the lowest (98.5) were obtained from (70x100cm) and (30x60cm) intra-row and inter-row spacing combinations respectively (Table 2)

The highest number of branches per plant (109.4) and the lowest (46.4) were obtained from (70x100cm) and (30x60cm) intra-row and inter-row spacing combinations respectively (Table 2). Generally, with decreasing intra and inter-row spacing number of branches per plant was decreased. Other reports also showed the lowest branches number per plant at the highest planting density, while higher branches number per plant at lower density. For instance, Sangoil (2000) explained that the reduction in branches number per plant with deceasing intra and inter-row spacing is due to greater inter-plant competition for incident light, soil nutrition, soil water and mutual shading of each other at high plant density than at low plant density. There is also failure of auxiliary buds to initiate branches or death of branches at higher density due to competition for assimilates between vertical and lateral growth. On the other hand, higher branch number per plant at the lower plant densities is due to less inter plant competition for assimilates.

3.3. Seed yield

Combined mean analysis result showed that the main and interaction effects of intra and inter-row spacing were highly significant ($P<0.0001$) on seed yield (Table 1). This result is similar with Higgins (1968), who reported that under narrow intra-row spacing and higher population density smaller plants of Vernonia were crowded out and disappeared. This self-thinning effect is a result of increased interplant competition for space, light, moisture and nutrients at the higher populations. Hence, at wider spacing the final plant stand per meter square can be higher than that of narrow spacing. The highest seed yield (2491.3 kg ha^{-1}) and lowest seed yield (1391.7 kg ha^{-1}) were obtained from 60cm X 60cm and 30 cm X 70cm intra and inter row spacing combinations respectivel (Table 3). This result is close to the research finding in Zimbabwe that showed seed yields of Vernonia galamensis varied from 1822 to 2469 kg/ha (Teynor et al., 1992).

One of the most common explanations for narrow-row seed yield enhancement is the attainment of sufficient leaf area index (LAI) to produce maximal light interception during seed formation (Shibles and Weber, 1966). Board et al. (1990), narrow-row spacing at normal and high densities had significantly higher yield than wide rows. According to the study made by Board et al. (1990), narrow-row spacing had significantly higher yield than wide rows. On other hand, according to Henderson et al. (2000), reduced inter plant competition and plant mortality were observed at the lowest plant population, compared with the higher plant population that results in increase in grain yield per plant at wider spacing. Further, greater seed yield per plant at wider spacing accrued from greater number of flower heads and hence greater number of seeds per plan. Other studies also showed similar responses (Turk et al., 1980; Pal, 2004). However, higher seed yield per plant at inter and intra spacing combinations that are wider than optimum does not grantee higher total yield per unit area.

Table 3
The interaction effect of intra-row and inter-row spacing on mean performance values of seed weight (kg/ha)/ grain yield) and oil yield (kg/ha) of Venonia galamanisis. Cass**.**

Intra-row spacing (cm)	Inter-row spacing					
	Seed weight (kg/ha)/ grain yield			Oil yield kg/ha		
	60 Inter	80 Inter	100 Inter	60 Inter	80 Inter	100 Inter
30	1391.7ef	1772.1c	1449.1de	507.1de	640.4c	538.1de
40	1488.5de	1558.8cde	1442.8de	560.4cd	580.7cd	529.5de
50	2041.8b	1405.7def	1211.6df	764.1b	513.5de	437.2ef
60	2491.3a	1402.6def	1162.5dh	932.2a	513.7de	439.8ef
70	1617.7cb	1191.6fdh	971.7h	580.3cd	451.6ef	366.5f
LSD		221.3***			101.6***	
CV		12.8			15.9	

Means followed by the same letters with in columns does not differ significantly at 0.05 probability level.

3.4. Oil yield

The oil yield of Vernonia galamensis (Cass.) was influenced highly significantly (P<0.0001) by main and interaction effects of inter and intra-row spacing treatments. The highest oil yield (932.2 kg/ ha) and lowest (366.5 kg /ha) oil yield were obtained from 60cm x 60cm and 70 cm X 100cm intra-row and inter-row spacing combinations respectively(Table 3). The result showed that 60cm and 60cm intra-row and inter-row spacing combination were found to be the optimum for highest oil yield of Vernonia galamensis (Cass.) above or below this spacing distance, oil yield significantly decreased. These results are in agreement with Dahmardeh et al (2010), Bakry et al (2011) and Yucel (2013). Perdue et al. (1986) also indicated that vernonia grown at narrow plant spacing produced higher oil yield per ha than that of wider plant spacing's.

3.5. Association among yield and yield components

The increasing in oil yield at higher densities may be due to the contribution of higher grain yield. This is supported by the very highly significant and positive correlation between oil yield and seed yield. (Correlation coefficient = 0.96797***) (Table 4). There was positive association between number of branches and number of capsules or pods per plants (correlation coefficient=0.34976**). The negative association of number of branches per plant with seed and oil yield indicates that yield attributes per plant bases were lower at higher density (at narrow plant spacing) and reduction in these attributes compensated with greater total plant stand and yield per unit area at narrow spacing.

Table 4
Association among growth, yield and yield related characters of vernonia tested under varying intra and inter-row spacing's.

	PH	NB	NC	SW kg ha^{-1}	OY kg ha^{-1}	OC%	TSW
PH	1						
NB	0.00574ns	1					
NC	-0.25986*	0.34976**	1				
SW kg ha^{-1}	0.11752ns	-0.09848ns	0.08733**	1			
OY kg ha^{-1}	0.09710	-0.14224ns	0.01654ns	0.96797***	1		
OC	-0.09698ns	-0.10979***	-0.03293ns	0.24697**	0.26832**	1	
TSW	0.04478ns	-0.05357ns	0.01136ns	0.07846ns	0.09696ns	0.01449ns	1

***= Significant at p < 0.001; **= p < 0.01; *= p < 0.05 probability level; and ns= non-significant at 0.05 probability level; PH= Plant height, NB= Number of branch per plant, NB= Number of capsules per plant, Seed weight, OY=Oil yield, OC=Oil content TSW=1000-seed weight.

4. Conclusion

The combined analysis of the two year results revealed that, the maximum seed yield and oil yield (2491.3 kg ha^{-1} and 932.2 kg ha^{-1}) respectively were obtained from 60cm*60cm intra row and inter row spacing combination. Therefore, optimum spacing of 60cm*60cm is recommended to attain maximum yield of *Vernonia galamensis (Cass.)* at Wondogenet and similar areas of Ethiopia.

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