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Effects of Seed Rate and Row Spacing on Growth, Yield Components and Yield of Coriander at Highland and Mid-Altitudes of Bale, South-Eastern Ethiopia

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Abstract: The productivity of coriander is affected due to an appropriate use of row spacing and seed rate practices at Bale. Therefore, an on farm experiment was conducted to determine the effects of different seed rates and row spacing on growth, yield components and seed yield of coriander. The treatments are consisted of factorial combinations of three seed rates (12, 15 and 18 kg ha^{-1}) and four row spacing (25, 30, 35 and 40 cm) in Randomized complete block design with three replications. The highest number of secondary branches per plant (4.10) and (3.89) was obtained from 18 kg ha^{-1} seed rate and 40 row spacing respectively. The highest number of umbels per plant (17.36) and (17.58) were obtained from 15 kg ha^{-1} seed rate and 35 cm row spacing respectively. The highest biomass yield (6000 kg ha^{-1}) and (6098 kg ha^{-1}) were obtained from 18 kg ha^{-1} seed rate and 40 cm row spacing respectively. The maximum plant height (82.83cm) was recorded from 18 kg ha^{-1} seed rate and 25 cm row spacing of coriander. The highest number of primary branches per plant was obtained from 15 kg ha^{-1} seed rate and 35 cm row spacing. The maximum seed yield (2714 kg ha^{-1}) was obtained from seed rate of 15 kg ha^{-1} and 35 cm row spacing. Therefore, based on the results of the yield and other growth and yield parameters use of 15 kg ha^{-1} seed rate and 35 cm row spacing can be tentatively recommended for farmers for production of coriander in the study area.

Keywords: Seed Rate, Row Spacing, Umbels, Coriander, Branches, Seed Yield

1. Introduction

Coriander (*Coriandrum sativum* L.) which belongs to the family Apiaceae (Umbelliferae) is mainly cultivated from its seeds throughout the year [1]. The yield and growth performance of coriander is depending on the variety, soil type, seed rate (plant population), dose of fertilizer applied and other management practices. Optimum seed rate and row spacing plays an important role in resulting to the high yield, because, thick plant population do not get proper light for photosynthesis and can easily be attacked by diseases and other pests. Optimum plant spacing and seed rate should be ensured for the plant to grow properly in order to give higher yield [2].

In the study area, Bale Zone, coriander is cultivated as common seed spice crop, in mid and high altitudes. However, the productivity per hectare is low because of many constraints. One of the principal production constraints of coriander is poor agronomic, lack of improved varieties, weeds, diseases and insect pests. Among the production techniques the important agronomic management practices like row spacing, seed rate and nutrient management practices plays an important role in improving the productivity of the coriander. Therefore, the objective of the study was to determine the effects of different seed rates and row spacing on growth, yield components and seed yield of coriander.

2. Materials and Methods

2.1. Description of Study Area

The experiment was conducted at Sinana (station), Goro and Ginir during 'Bona' cropping season for two constitutive years from 2021-2022. All the locations have bimodal rainfall patterns. The major crops grown widely at Sinana (are cereals (wheat, barley, maize and *tef*, pulses (chickpea, field pea, faba bean, and lentil) and vegetables (onion, garlic, potato and tomato) and at Goro and Ginir (wheat, barley, maize, *tef*, chickpea, field pea, faba bean, lentil and seed spices (black cumin, coriander and fenugreek) under rain fed and irrigation.

2.2. Experimental Materials and Treatments

The variety 'Gadisa' was used as testing planting material. The experiment was consisting of factorial combinations of three seed rates (12, 15 and 18 Kg ha^{-1}) and four row spacing (25, 30, 35 and 40 cm) and were laid out as a Randomized complete block designs (RCBD) in three replications.

2.3. Experimental Procedure and Field Management

The experimental field was cultivated and disked by tractor and pulverized to a fine tilth by hand digging. Blocking and the required number of rows were marked in each plot according to the spacing proposed and rows were made to plant the seeds. The plots were smoothed manually. The gross plot size of 2.8 m x 3 m (8.4 m^2) which is a constant area having different rows for the plot was used. The middle rows were used for data collection. The Land preparation, fertilizer application, planting and other management practices were applied as per the recommendations of the crop.

2.4. Data Collected and Measurement

Phonological, yield components and yield data such as days to 50% flowering, days to 90% physiological maturity, plant height, number of primary branches per plants; number of secondary branches per plants, number of umbels per plants, above ground dry biomass yield (kg ha^{-1}), seed yield and harvest index were collected and subjected to analysis of variance (ANOVA) procedure using [3]. Comparisons among treatment means with significant difference for measured characters were done by Fisher's protected Least Significant Difference (LSD) test at 5% level of significance.

3. Results and Discussion

Table 1. *Mean squares of ANOVA for phenological parameters and yield of coriander as affected by seed rate and row spacing.*

Source	df	Mean squares								
		DF	DM	PH	NPBPP	NSBPP	NUPP	BY	SY	HI
Block	2	14.13	11.17	7.06	0.42	0.58	1.1	44615	20256	7.19
SR	2	9.02^{ns}	9.88^{ns}	5.75^{ns}	0.04**	0.40**	8.43*	1626157**	64104*	105.13^{ns}
RS	3	44.89*	33.45**	10.32^{ns}	0.10^{ns}	0.02*	2.54*	1788233**	18675*	105.96^{ns}
SR × RS	6	5.54^{ns}	7.17^{ns}	10.05*	0.07*	0.02^{ns}	1.60^{ns}	154936^{ns}	13645**	8.12^{ns}
Error	22	21.57	3.96	7.899	0.04	0.07	2.32	74267	21394	12.30
CV (%)		5.6	1.5	3.6	5.4	13.0	9.3	4.8	5.7	7.6

Where; SR=seed rate; RS= row spacing; df= degree of freedom; DF= days to flowering; DM= Days to maturity; NPBPP=number primary branches per plant; NSBPP=Number of secondary branches per plant; NUPP=number umbels per plant; BY=Biomass yield; SY=seed yield; HI=harvest index.

3.1. Days to 50% Flowering

The results from the analysis of variance indicated that row spacing have a significant ($P < 0.05$) effect on days to 50% flowering while seed rate and the interaction between seed rate and row spacing did not significant for required to 50% flowering (Table 1). The shortest days (80.06 days) to reach days to 50% flowering was observed at 25cm row spacing while the longest days (85.33 days) to reach days to 50% flowering was observed at 40 cm row spacing which is statistically at par with 30 cm and 35 cm of row spacing (Table 4). This is due to the wider spacing resulted in profuse branching which might have helped in larger canopy development and delayed plant to attain reproductive phase. In line with this research [4] reported that earliest flowering observed at closure spacing (20 cm) as compared to wider spacing of 30 and 40 cm in coriander.

3.2. Days to 90% Physiological Maturity

The analysis of variance indicated that number of days required to reach physiological maturity was highly significantly ($p<0.01$) affected by main effect of row spacing while seed rates and the interaction between seed rate and row spacing did not significantly influenced the number of days required to reach 90% physiological maturity (Table 1). The shortest days (133.3 days) to reach days to 90% maturity was observed at 25 cm row spacing while the longest days (137.3 days) to reach days to 90% maturity was observed at 40 cm row spacing which is statistically at par with 30 cm and 35 cm of row spacing (Table 4). This is due to availability of large space per plant resulted in profuse vegetative growth and delayed plant to attain productive growth.

3.3. Plant Height

Plant height was significantly ($p<0.05$) affected by the interaction of seed rate and row spacing (Table 1). The highest plant height (82.83cm) was recorded from 18 kg ha^{-1} seed rate and 25 cm row spacing while the lowest plant height (75.82cm) was recorded from 15 kg ha^{-1} seed rate and 40 cm row spacing (Table 2). This might have decreased the availability of light to the plants. The reduced light intensity at the base of the plant stem might have accelerated elongation of lower internodes resulting in plant height. The significant increase in plant height from early stage of crop growth under closer row spacing and high seed rate seems to be due dense population. Similarly, the author [5] in cumin showed the plant height was strongly influenced by seed rate and increased seed rate tends to increase in plant height. The highest plant height was found in lower seed rate and lower in the maximum seed rate of coriander as reported [6]. These observations are in close conformity with finding of [7].

Table 2. *The interaction effect of seed rate and row spacing on plant height of coriander.*

Seed Rate (kg ha^{-1})	Row Spacing (Cm)			
	25	30	35	40
12	78.73 ab	78.94 ab	77.97 ab	78.93 ab
15	78.02 ab	77.04 ab	77.92 ab	75.82 b
18	82.83 a	77.70 ab	77.28 ab	76.41 b
$LSD_{0.05}$ = 4.76	CV (%) =3.6			

Means followed by the same letter(s) in the table are not significantly different at 5% level of significance; P= P_2O_5 fertilizer rate; LSD=Least significance difference at 5% probability level and CV=Coefficient of variation.

3.4. Number of Primary Branches Per Plant

The analysis of variance showed that the main effect of seed rate was highly significant ($p<0.01$) and the interaction between seed rate and row spacing significantly ($p<0.05$) influenced the number of primary branches per plant (Table 1). However, there was no significant variation by row spacing in number of primary branches per plant. The highest number of primary branches per plant was gained from 18 kg ha^{-1} seed rate and 35 cm row spacing while the lowest number of primary branches per plant was obtained from 12 kg ha^{-1} and 25 cm seed rate and row spacing respectively (Table 3).

Significant improvement in number of primary branches per plant was due to increase in spacing or in other words reduction in plant population per unit area could be attributed to availability of more area per plant which implied that individual plant at wider spacing received higher growth inputs (sunlight, water and nutrients) with least competition compared to the plants grown under closer spacing and higher seed rate. A significant improvement in growth with close spacing was agreed with the findings [8, 9]. The number of primary branches significantly increased with increasing row spacing as stated [10].

Table 3. *The interaction effect of seed rate and row spacing on number of primary branches of coriander.*

Seed Rate (kg ha^{-1})	Row Spacing (Cm)			
	25	30	35	40
12	3.59 c	3.91 abc	4.0 ab	3.70 abc
15	3.67 bc	3.82 abc	4.10 a	3.78 abc
18	3.72 abc	3.93 abc	3.73 abc	3.72 abc
$LSD_{0.05}$ =0.35	CV (%) = 5.4			

Means followed by the same letter(s) in the table are not significantly different at 5% level of significance; P= P_2O_5 fertilizer rate; LSD=Least significance difference at 5% probability level and CV=Coefficient of variation.

3.5. Number of Secondary Branches Per Plant

The main effect of seed rate was highly significantly ($p<0.01$) influenced the number of secondary branches produced per plant while row spacing was significantly ($p<0.05$) influenced this parameter (Table 1). The interaction of seed rate and row spacing did not influence the number of secondary branches per plant (Table 3). The highest number of secondary branches per plant (4.10) and (3.89) was obtained from 18 kg ha^{-1} seed rate and 40 cm row spacing respectively, while the lowest number of secondary branches per plant was obtained from low seed rate and closer spacing of coriander (Table 4). The larger canopy development associated with profuse branching had increased interception, absorption and utilization of solar energy resulting information of higher photosynthesis and finally dry matter per plant. The results were in line with the observations [10] which stated that the number of secondary branches significantly increased with increasing row spacing and lower seed rate.

3.6. Number of Umbels Per Plant

The analysis of variance showed significant ($p<0.05$) effect of seed rate and row spacing on the number of umbels per plant while the interaction between seed rate and row spacing of coriander did not show significant effect on this parameter (Table 1).

The highest number of umbels per plant (17.36) and (17.58) were obtained from 15 kg ha^{-1} seed rate and 35 cm row spacing respectively. The lowest number of umbels number per plant (15.75) and (15.67) were obtained from 12 kg ha^{-1} seed rate and 25 cm row spacing respectively (Table 4). The results of the number of umbrella per plant were agreed with the findings [11].

Table 4. *Combined effect of Main effects of seed rate and row spacing on number of days to 50% day to flowering, number of days to 90% maturity, number of secondary branches per plant, Number of umbels per plant, biomass yield and harvest index of coriander.*

Treatment	Days to 50% Flowering	Days to 90% maturity	Number of secondary branches	Number of umbels per plant	Biomass yield ($Kgha^{-1}$)	Harvest Index (%)
Seed Rate (kg ha^{-1})						
12	81.96	135.2	3.59 b	15.75 b	5265 c	47.41
15	82.71	136.5	3.37 b	17.36 a	5664 b	48.19
18	83.69	137.0	4.10 a	16.16 ab	6000 a	42.72
LSD	NS	NS	0.41	1.29	230.73	NS
Row Spacing (cm)						
25	80.06 b	133.3 b	3.29 b	15.67 b	5102 c	49.79
30	82.17 ab	137.1 a	3.77 b	16.18 ab	5794 b	48.08
35	83.58 ab	137.1 a	3.80 a	17.58 a	5901 ab	44.20
40	85.33 a	137.3 a	3.89 a	16.11 ab	6098 a	42.34
LSD	4.5	1.95	0.47	1.51	266.42	NS
CV (%)	5.6	1.5	13.0	9.3	4.8	7.8

Means followed by the same letter(s) in the table are not significantly different at 5% level of significance; LSD=Least significance difference at 5% probability level; CV=Coefficient of variation.

3.7. Aboveground Biomass

The main effect of seed rate and row spacing were highly significant ($P<0.01$) on the aboveground biomass. However, neither the interaction effect of seed rate and row spacing did not significantly influence aboveground biomass (Table 1). The highest biomass yield (6000 kg ha^{-1}) and (6098 kg ha^{-1}) were obtained from 18 kg ha^{-1} seed rate and 40 cm row spacing respectively; whereas the lowest biomass (5265 kg ha^{-1}) and (5102 kg ha^{-1}) were recorded from lowest seed rate and narrow spacing respectively (Table 4). Enhancement in yield and yield attributes of the crop with increase in spacing appear to be on account of vigorous growth of the plants as evident from profuse branching and higher biomass accumulation per plant. The profuse branching seems to have led to greater initiation of flowering and adequate supply of metabolites due to the increase in biomass per plant might have helped in retention of flower thereby greater seed formation and seed growth. These results justify that overpopulation of plants at closer spacing significantly reduced growth and yield attributes of the crop but compensated the yield to a certain level. This result is in line with the author [4] who noticed that the higher biological yield (4152 $kgha^{-1}$) was gained with a row spacing of 30 cm as compared with 20 and 40 cm in coriander.

3.8. Harvest Index

The difference in harvest index was observed to be non-significant for main effects of seed rate and row spacing of. Similarly, significant variation was also not observed by the interactions of the two factors (Table 1). The observed harvest index varies from 42.34 to 49.79%. In contract to this article [4] noticed that higher harvest index (36.06%) obtained with a row spacing of 30 cm as compared with 20 and 40 cm in coriander crop.

3.9. Seed Yield

The main effects of seed rate and row spacing were significant ($p < 0.05$) to influence the seed yield of the coriander. The two factors are also interacted highly significantly ($p < 0.01$) to affect the seed yield of the coriander (Table 1). The highest seed yield (2714 kg ha^{-1}) was recorded from seed rate of 15 kg ha^{-1} and 35 cm row spacing while the lowest seed yield (2417 kg ha^{-1}) was recorded from 12 kg ha^{-1} and 25 cm seed rate and row spacing respectively (Table 5). This is due to more plants per unit area though, improved over all growth of crop but failed to record highest yield due to less number of plants per hectare. Significantly higher chlorophyll content of leaves and essential oil content of seed under wider spacing could be ascribed due to availability of large space per plant resulted in profuse vegetative growth and delayed plant to attain productive growth. In line with this result [4] who reported that the medium spacing gave higher seed yield than wider spacing in coriander.

Table 5. *The interaction effect of seed rate and row spacing on seed yield of coriander.*

Seed Rate (kg ha^{-1})	Row Spacing (Cm)			
	25	30	35	40
12	2417 c	2547 ab	2610 ab	2488 ab
15	2444 b	2593 ab	2714 a	2580 ab
18	2495 ab	2593 ab	2628 ab	2466 ab
$LSD_{0.05}$ = 247.67	CV (%) = 5.7			

Means followed by the same letter(s) in the table are not significantly different at 5% level of significance; LSD=Least significance difference at 5% probability level; CV=Coefficient of variation.

4. Conclusion and Recommendation

Analysis of variance revealed that the number of days to 50% flowering and number of days required to 90% physiological maturity were significantly influenced by main effect of row spacing while number of secondary branches and number of umbels per plant were significantly affected by main effects of both seed rates and row spacing. Similarly, biological yield was significantly affected due to main effect of seed rates. The shortest days (80.06 days) to reach days to 50% flowering was observed at narrow row (25 cm) spacing while the longest days (85.33 days) to reach days to 50% flowering was observed at wider (40 cm) row spacing. The shortest days (133.3 days) to reach days to 90% maturity was observed at 25 cm row spacing while the longest days (137.3 days) to reach days to 90% maturity was observed at 40 cm row spacing which is statistically at par with 30cm and 35 cm of row spacing.

The highest number of secondary branches per plant (4.10) and (3.89) was obtained from 18 kg ha^{-1} seed rate and 40cm row spacing respectively, while the lowest number of secondary branches per plant was obtained from 12 kg ha^{-1} seed rate and 25 cm row spacing of coriander. The highest number of umbels per plant (17.36) and (17.58) were obtained from 15 kg ha^{-1} seed rate and 35 cm row spacing respectively. The lowest number of umbels number per plant (15.75) and (15.67) were obtained from 12 kg ha^{-1} seed rate and 25cm row spacing respectively. The highest biomass yield (6000 kg ha^{-1}) and (6098 kg ha^{-1}) were obtained from 18 kg ha^{-1} seed rate and 40 cm row spacing respectively; whereas the lowest biomass (5265 kg ha^{-1}) and (5102 kg ha^{-1}) were recorded from lowest seed rate and narrow spacing respectively. The interaction effects of seed rates and row spacing significantly affected plant height, number of primary branches per plant and seed yield. The highest plant height (82.83 cm) was recorded from 18 kg ha^{-1} seed rate and 25 cm row spacing while the lowest plant height 75.82 cm was recorded from 15 kg ha^{-1} seed rate and 40 cm row spacing. The highest number of primary branches per plant was obtained from 15 kg ha^{-1} seed rate and 35 cm row spacing while the lowest number of primary branches per plant was obtained from 12 kg ha^{-1} and 25 cm seed rate and row spacing respectively. The highest seed yield (2714 kg ha^{-1}) was recorded from seed rate of 15 kg ha^{-1} and 35 cm row spacing while the lowest seed yield (2417 kg ha^{-1}) was recorded from 12 kg ha^{-1} and 25 cm seed rate and row spacing respectively.

Marked improvement in yield and yield attributes of the crop with increase in spacing appear to be on account of vigorous growth of the plants as evident from profuse branching and higher biomass accumulation per plant. The results justify that overpopulation of plants at closer spacing significantly reduced growth and yield attributes of the crop but compensated the yield to a certain level. On the other hand, due to more plants/unit area though, improved over all growth of crop but failed to record highest yield due to less number of plants per hectare. Therefore, based on the results of the yield and other growth and yield parameters use of 15 kg ha^{-1} seed rate and 35 cm row spacing can be tentatively recommended for farmers for production of coriander in the study area.

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