Determination of Optimum Plant Spacing on Growth and Yield of Chinese cabbage in Ethiopia

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Abstract

Chinese cabbage is an important leafy and herbaceous vegetable crop. It is a fast-growing vegetable crop with a comparatively short vegetation period, source of minerals, proteins, and antioxidants. But, optimum plant spacing of Chinese cabbage is not determined, since the crop is new in Ethiopia. Therefore, the field experiment was conducted at Melkassa, Kulumsa and Debre Zeit Agricultural Research Centers during 2020 and 2021 main rainy season to determine the effects of plant spacing on growth and yield of Chinese cabbage. The experiment was laid out in factorial Randomized Complete Block Design (RCBD) with three replications. The experiment consisted three levels of inter row spacing (40, 50 and 60 cm) and three levels of intra row spacing (30, 40 and 50 cm). The analysis of variance revealed that the interaction and main effects of inter and intra row spacing didn't show significant difference on plant width, head weight, head length and head diameter. However, the main effect of inter and intra row spacing showed significant difference ($P<0.05$) on plant height. The longest plant height was recorded at 40 cm and 30 cm inter and intra row spacing, respectively, while the shortest height was obtained from 60 cm and 50 cm inter and intra row spacing, respectively. The interaction and main effects of inter and intra row spacing showed non-significant difference on marketable and total yield at Melkassa and Kulumsa during 2021, however, both traits showed significant difference at Debre Zeit on the same year 2021.The overall combined analysis showed significant difference ($P<0.05$) on marketable and total yield. The highest total yield recorded was 518.59 qt ha^{-1} and 534.30 qt ha^{-1}at 40 cm inter and 30 cm intra row spacing, respectively. However, the lowest total yield (403.84 qt ha^{-1} and 385.42 qt $ha^{-}1$) was obtained ^{at} 60 cm inter and 50 cm intra row spacing from overall combined analyses. Therefore; from the results obtained, it is recommended to use 40 cm and 30 cm inter and intra row spacing, respectively for the testing environments and similar agro-ecologies in the country for Chinese cabbage productions.

Keywords: Planting density, inter and intra row spacing, fresh yield, competition

Introduction

Chinese cabbage (*Brassica rapa* L. *var pekinensis*) is an important leafy and herbaceous vegetable crop that originated from China and belongs to the family *Crucifereae* (Rashid, 1999). It is a fast-growing vegetable crop with a comparatively short vegetation period that depending on the variety and growing conditions; lasts approximately 50 to 80 days (Staugaitis *et al.,* 2008).

It is a good source of minerals, proteins, and antioxidants and has low calories, fats, and carbohydrate, contents (Singh *et al.,* 2004). Currently, Chinese cabbage is gaining high popularity in all over the world as potherb, salad as well as cooked vegetable (Singh *et al*, 2004). The crop has good taste and high nutritional value, leads the demand for this vegetable crop is rising constantly in all growing areas. Chinese cabbage is characterized by high ability to adapt to a wide range of habitats and agro-ecologies to grow (Maršalkienėet *et al*., 2014).

In Ethiopia, Chinese cabbage is not grown so far by commercial farms; however, it is being cultivated by Agricultural Research Center and innovative farmers at small scale level by using local varieties. It is gaining immediate attention to cultivate this crop in the East Shoa Zone, especially at Bishoftu areas due to high preferences by foreigners who live in Addis Ababa for their consumption. Recently two Chinese cabbage varieties were released by Melkassa Agricultural Research Center without its production packages. Agronomic production packages such as plant spacing and population density and nutrient requirements of the Chinese cabbage still unknown by the growers, Therefore, information on plant spacing and population density are the most important agronomic practices for growth and yield of Chinese cabbage in the country (Sarker *et al.*, 2002; Sumat *et al*., 2018).

Plant density for Chinese cabbage production is an important criterion for attaining maximum yield. Closer spacing can help to reduce weeds, enhance soil protection, increase fertilizers efficiency, and increase yields (Neto *et al*. 2016). Wider spacing ensures the basic requirements of the plant, but decreases the total number of plant as well as total yield (Moniruzzaman, 2011). Chinese cabbage yield and quality response to plant density has been influenced by soil, water regimes, nutrient status, and market requirements (Tiwari *et al.*, 2003). Total and marketable yield of Chinese cabbage plant height have been increased with increasing plant density at closer plant spacing (Znidarcic *et al*., 2007). Yield may be increased up to 25% by using optimum spacing (Bansal *et al*., 1995). Increase of plant density determined the reduction of chinesse cabbage head weight by 48.5% (Scuderi, *et al.*, 2013). Total yield of Chinese cabbage increases with narrow plant spacing, the average head weight decreases due

to air, light and nutrient competition (Khan *et al*., 2015). Dense planting can produce higher head yield owing to the presence of a greater number of plants per unit area. Proper spacing is an important factor for securing a higher yield of Chinese cabbage (Moniruzzaman, 2011). Hence, the current study was conducted to evaluate the effects of plant spacing on growth and yield of Chinese cabbage and to determine optimum plant spacing for Chinese cabbage production.

Materials and Methods

Description of study area

The experiment was conducted at Melkassa, Debre Zeit and Kulumsa Agricultural Research Centers during 2020 and 2021 main rainy season. Melkassa is found 117 km South East of Addis Ababa with geographic co-ordinate of $8^{o}24'$N latitude and $39^{o}12'$E longitude. It situated at an altitude of 1550 m.a.s.l. The area receives mean annual rainfall of 763 mm, about 70% of which received during the main rain season from June to September. The mean annual maximum and minimum temperature of the site is about 28.6^{0}C and 13.8^{0}C, respectively. The agro-climatic condition of the area is classifying as semi-arid. The soil texture is dominantly loam and clay loam (MARC, 1994). Available soil water lies between 34.04% at field capacity and 16.74% at permanent wilting point on dry weight basis. The average bulk density of the soil in depth of 0-90cm is 1.13g/cm^3. The soil is slightly alkaline ranging from 7.4-7.6 pH (Mesfine *et al.*, 2005). Kulumsa Agricultural Research Center (KARC) is located at 8°00‟ to 8 o 02‟N latitude and 39°07‟ to 39°10‟E longitude with an altitude of 2200 m.a.s.l. The annual minimum and maximum temperatures of 10 and 22°C and the soil texture is Luvisol soils in Tiyo district, Arsi Administrative Zone. Debre Zeit Agricultural Research Center has an altitude of 1860 m.a.s.l, annual minimum and maximum temperatures of 8.9 and 28.3°C with Alfisol soil texture. It is located 35 km east of Addis Ababa and its geographic location is at $08^{0}57'15$" north latitude and $39^{0}06'04$" east longitude (EIAR, 2021).

Experimental design and treatment

The experiment was laid out in 3x3 factorial arrangements in a Randomized Complete Block Design (RCBD) with three replications. It consists three levels of inter row spacing (40, 50 and 60 cm) and three levels of intra row spacing (30, 40 and 50 cm). Area of each experimental plot was 7.2 m^2 (2.4m x 3m). Each experimental plot was consisted four rows; the 2nd and 3rd rows harvestable row; the 1st and 4th rows were border rows. The spacing between plots and blocks was 1.5 m.

Experimental procedures

The land preparation involved plowing using a tractor, followed by disking and harrowing to ensure proper soil preparation. All cultural practices, including weeding and cultivation, were uniformly applied to all plots. For the experiment, the well-adapted and high-yielding Chinese cabbage variety 'Mi'o-1' was selected. Seedlings were raised on seed bed and transplanted in to the experimental plots after 25 days of emergence. The required agronomic practices such as watering, cultivation, fertilization and weeding were uniformly applied to all plots according to standard vegetable crop production procedures.

Data to be collected

Plant height (cm) was measured from the base of the plant to the apical bud from five plants in each plot. Plant width (cm) was measured from horizontal distance covered by the plant. Total yield (kg) was recorded as the whole plant weight of all the plants within a plot which includes weight of plant head, unfolded leaves and stem. Marketable yield ($qt\ ha^{-1}$): The weight of all compact head excluding unfolded leaves and stem produced in a plot was taken and converted into yield per hectare. Length of head (cm): calculated from three sample plants which was measured from the base to the tip of head after removing unfolded leaves. Diameter of head (cm): The heads from five sample plants was sectioned vertically at the middle position with a sharp knife. The diameter of the head was measured as the horizontal distance from one side to another side of the widest part of the section head and mean value was recorded. Fresh weight of head per plant: The heads from five sample plants was cleaned by removing unfolded leaves and average head weight (g) was recorded.

Statistical data analysis

All data were subjected to analysis of variance using the GLM procedure of the SAS software version 9.0 (SAS, 2004). The assumptions of ANOVA for normality of distribution and homogeneity of variance were checked and statistical analysis was done; where the F-ratios was found to be significant, mean separation was performed using LSD at the 5% probability level.

Results and Discussions

Plant height

The interaction effect showed non-significant difference, but main effect of inter and intra row spacing indicated significant difference ($P<0.05$) on plant height of Chinese cabbage. The longest height was recorded at closer spacing at 40 cm (23.32 cm) and 30 cm (23.04 cm) inter and intra row spacing, respectively; while the shortest plant height was obtained at wider spacing of 60 cm (21.04 cm) and 50 cm (21.71 cm) inter and intra row spacing, respectively. Increased plant density coupled with shallow root system limits the availability of space for lateral growth. This leads to the competition between

the plants for light and nutrients, resulting in increased plant height. These findings agreed with Moniruzzaman (2011) in head cabbage and Hill (2000) in Chinese cabbage.

Plant width, head weight, head length and head diameter

The interaction and main effect of inter and intra row spacing didn't show significant difference on plant width, head weight, head length and head diameter. Narrow plant spacing reduced head size and head weight due to air, light and nutrient competition (Stepanović *et al.*, 2000; Khan *et al*., 2015).

Table 1. Combined analysis of plant height, plant width, head weight, head length and head diameter during 2020 & 2021

Inter rows	Plant height (cm)	Plant width (cm)	Head weight (kg)	Head length (cm)	Head diameter (cm)
40	23.32a	38.90	1.06	19.93	14.19
50	22.31a	38.92	1.08	19.21	14.70
60	21.04b	38.93	1.15	19.57	13.91
F-test	**	NS	NS	NS	NS
Intra rows					
30	23.04a	39.25	1.06	19.49	14.61
40	21.90b	38.88	1.14	19.37	14.40
50	21.71b	38.61	1.10	19.86	13.79
F-test	*	NS	NS	NS	NS
LSD (0.05)	1.04	2.16	0.18	1.31	1.17
CV (%)	11.24	13.34	26.23	16.06	19.70

Marketable yield

The interaction and main effect of inter and intra row spacing didn't show significant difference ($p>0.05$) on marketable yield at Melkassa and Kulumsa during 2021 cropping season. However, the main effect of inter and intra row spacing had significant difference on marketable yield at Debre Zeit during 2021. The highest marketable yields (190.80 qt ha^{-1} and 177.42 qt ha^{-1}) were recorded at 40 cm inter and 30 cm intra row spacing, respectively. But the lowest marketable yields (98.69 qt ha^{-1} and 114.51 qt ha^{-1}) were obtained at 60 cm and 50 cm inter and intra row spacing, respectively.

In 2021, the main effect of inter and intra row spacing had significant difference ($p<0.05$) on marketable yield at both Kulumsa and Debre Zeit. The highest marketable yields (425.50 qt ha^{-1} and 429.28 qt ha^{-1}) were recorded from inter (40 cm) and intra row (30 cm) spacing, respectively for the latter two locations. The lowest marketable yields (252.22 qt/ha and 285.32 qt ha^{-1}) were however obtained from inter (60 cm) and intra row (50 cm) spacing, respectively at Kulumsa.

The highest marketable yield was recorded 531.34 *qt ha^{-1}* and 529.53 *qt ha^{-1}* at 40 cm and 30 cm inter and intra row spacing, respectively. While, the lowest marketable yield was obtained 332.22 *qt ha^{-1}* and 341.21 *qt ha^{-1}* at 60 cm and 50cm inter and intra row spacing, respectively at Debre Zeit. In 2021 at Melkassa had non-significant difference on marketable yield.

In 2020 combined analyses variance didn't show significant difference on marketable yield, but during 2021 combined and over year analysis had showed significant difference (P<0.05) on marketable yield. The highest marketable yield was recorded (524.57 qt ha^{-1} and 527.19 qt ha^{-1}) at 40 cm and 30 cm inter and intra row spacing, respectively. But the lowest marketable yield was obtained (370.80 qt ha^{-1} and 386.10 qt ha^{-1}) at 60 cm and 50 cm inter and intra row spacing, respectively from combined analysis. The overall combined analysis of variance showed significant difference for intra row spacing (P<0.05) effect on marketable yield. The highest marketable yield was recorded at 30 cm intra rows spacing, while the lowest marketable yield was obtained at 50 cm intra rows spacing. As increasing plant density increased and yield of Chinese cabbage also increased Znidarcic *et al*. (2007).

Total yield

The interaction and main effect of inter and intra row spacing didn't show significant difference (p>0.05) on total yield at Melkassa and Kulumsa during 2021. But, the main effect of inter and intra row spacing had indicated significant difference (P<0.05) effect on total yield at Debre Zeit during 2021. The highest total yield was recorded (356.88 *qt ha^{-1}* and 326.03 *qt ha^{-1})* at 40 cm and 30 cm inter and intra row spacing, respectively. But the lowest total yield was obtained (174.84 *qt ha^{-1}* and 208.01 *qt ha^{-1})* at 40 cm and 30 cm inter and intra row spacing, respectively.

In 2021 the main effect of inter and intra row spacing had significant difference (P<0.05) on total yield at both Kulumsa and Debre Zeit. The highest total yield was recorded (443.94 *qt ha^{-1}* and 439.23 *qt ha^{-1})* at 40 cm and 30 cm inter and intra row spacing, respectively. The lowest total yield was obtained (260.77 *qt ha^{-1}* and 302.59 *qt ha^{-1})* at 40 cm and 30 cm inter and intra row spacing, respectively at Kulumsa. The highest total yield was recorded (629.30 *qt ha^{-1}* and 626.68 *qt ha^{-1})* at 40 cm and 30 cm inter and intra row spacing, respectively. But the lowest total yield was obtained (366.28 *qt ha^{-1}* and 385.91 *qt ha^{-1})* at 40 cm and 30 cm inter and intra row spacing, respectively at Debre Zeit. In 2021 at Melkassa, inter and intra row spacing had non-significant difference on total yield.

In 2020 combined analysis variance didn't show significant difference on total yield. But, 2021 combined and overall year combined analysis showed significant difference (P<0.05) on total yield. The highest total yield was recorded (579.47 *qt ha^{-1}* and 591.09 *qt ha^{-1})* at 40 cm and 30 cm inter and intra row spacing, respectively. While, the lowest total yield was obtained (411.05 qt/ha and 414.20 *qt ha^{-1}*) from the respective inter and intra row spacing.

Table 2. Overall marketable yield at Melkassa, Kulumsa and Debrezeit (qt/ha) during 2020 and 2021

	Year								
Inter rows	**2020**				**2021**				
	Melkassa	Kulumsa	D/Zeit	Comb	Melkassa	Kulumsa	D/Zeit	Comb	Over all
40	437.01	331.90	190.80a	319.90	616.87	425.50a	531.34a	524.57a	422.24
50	630.92	284.8	130.50b	348.77	598.77	368.07a	436.56b	467.80a	408.28
60	645.30	257.34	98.69b	333.78	527.47	252.22b	332.70c	370.80b	352.29
F-test	NS	NS	**	NS	NS	**	**	*	NS
Intra rows									
30	594.40	305.49	177.42a	359.10	622.77	429.28a	529.53a	527.19a	443.15a
40	632.80	318.70	128.06b	359.85	588.57	331.19b	429.86b	449.87ab	404.86ab
50	486.03	249.94	114.51b	283.50	531.77	285.32b	341.21c	386.10b	334.80b
F-test	NS	NS	*	NS	NS	**	**	**	**
LSD	211.72	116.83	43.91	132.88	185.91	88.48	81.26	83.97	80.77
CV (%)	25.67	30.79	30.09	30.95	28.78	24.39	19.06	22.14	28.88

Table 3: The overall total yield at Melkassa, Kulumsa and Debrezeit during 2020 and 2021

	Year								
Inter rows	**2020**				**2021**				
	Melkassa	Kulumsa	D/Zeit	Comb	Melkassa	Kulumsa	D/Zeit	Comb	Over all
40	570.36	445.87	356.88a	457.70	665.18	443.94a	629.30a	579.47a	518.59a
50	676.92	380.99	250.57b	436.16	642.09	344.00ab	493.33b	493.14ab	464.65ab
60	675.31	339.76	174.84c	396.64	606.11	260.77b	366.28c	411.05b	403.84b
F-test	NS	NS	**	NS	NS	*	**	**	*
Intra rows									
30	695.64	410.87	326.03a	477.51	707.36	439.23a	626.68a	591.09a	534.30a
40	700.42	420.36	248.24b	456.34	651.93	306.89b	476.32b	478.38b	467.36a
50	526.52	335.39	208.01b	356.64	554.09	302.59b	385.91b	414.20b	385.42b
F-test	NS	NS	**	NS	NS	*	**	**	**
LSD	202.49	143.39	68.20	124.51	187.96	109.53	95.31	99.96	78.39
CV (%)	27.12	29.10	25.86	28.81	28.89	30.8	19.53	25.26	29.15

of the combined analysis. The highest total yield was recorded (518.59 *qt ha*$^{-1}$ and 534.30 *qt ha*$^{-1}$*)* at 40 cm and 30 cm inter and intra row spacing, respectively. The lowest total yield was obtained (403.84 *qt ha*$^{-1}$ and 385.42 *qt ha*$^{-1}$*)* at 40 cm and 30 cm inter and intra row spacing, respectively from overall analyzed. This is due to the reality that as plant density increases (at closer plant spacing), total plant population increases and this in turn contributes to increase in total head yield. The current result is in agreement with Znidarcic *et al.*, (2007) and Hossain *et al.*, (2011).

Conclusion and Recommendations

Chinese cabbage is an important leafy and herbaceous vegetable crop. It is a fast-growing vegetable crop with a comparatively short vegetation period. But, the optimum plant spacing of Chinese cabbage was not determined since the crop is new in Ethiopia. Therefore; the effect of plant spacing on growth and yield of Chinese cabbage 'Mi'o-1' variety was studied on three locations for two seasons. The analysis of variance revealed that the interaction and main effect of inter and intra row spacing didn't show significant difference on plant width, head weight, head length and head diameter. However, the main effect of inter and intra row spacing had significant difference ($P<0.05$) on plant height. The tallest plant height was recorded at 40 cm and 30 cm inter and intra row spacing, respectively, while the shortest was obtained at 60 cm and 50 cm inter and intra row spacing, respectively. The interaction and main effect of inter and intra row spacing had non-significant difference on marketable and total yield at Melkassa and Kulumsa during 2021. Nevertheless, the main effect of inter and intra row spacing had significant difference on marketable and total yield at Debre Zeit during 2021. The overall combined analyses of variance showed significant difference ($P<0.05$) on marketable and total yield. The highest total yield of Chinese cabbage was 518.59 qt ha^{-1} and 534.30 qt ha^{-1} at 40 cm and 30 cm inter and intra row spacing, respectively. Therefore; from the results obtained it is recommended to use 40 cm and 30 cm inter and intra row spacing, for production of Chinese cabbage in the testing environments and similar agro-ecologies in the country.

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