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Preliminary Studies on Effect of Planting Geometry on Seed Yield and Seed Quality of Pak choi (*Brassica rapa* L. subsp. *chinensis* L.)

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ABSTRACT: A preliminary study was undertaken to compare the effect of different planting densities on seed yield and seed quality of pak choi (*Brassica rapa* L. subsp. *chinensis* L.) at the research farm of CPCT/ Division of Seed Science and Technology, ICAR-IARI, New Delhi during *rabi* 2019-20. Four plant spacing's viz., 60 x 45 cm, 60 x 30 cm, 45 x 30 cm and 30 x 30 cm were attempted to assess the effect on the growth, yield and seed quality attributes. The result exhibited that seed yield and yield attributes, namely plant height (88.8), number of primary branches per plant (6.3), number of secondary branches per plant (9.1), number of tertiary branches per plant (8.2), there were no silique on primary branches but the number of silique on secondary branches per plant (110.4) and tertiary branches per plant (45.2), number of seeds per silique (26.5), seed yield per plant (45.1 g) seed yield per secondary branch per plant (37 g) and per tertiary branch per plant (8.1 g) were found highest in spacing of 60 x 45 cm, but seed yield per hectare (2.14 t/ha) was found highest in spacing of 60 x 30 cm mainly due to higher plant population per hectare and optimum resource utilization in field per unit area. Seed quality attributes, such as 1000 seed weight (1.81 g), germination percentage (96 %), seedling vigour index I (663) and seedling vigour index II (18.9) were found highest in spacing of 60 x 30 cm. These investigations indicated that relatively better performance was observed in medium plant densities over higher and lower ones, particularly with respect to seed yield per hectare as well as seed quality attributes. Thus, it can be concluded that Pak choi should be planted with a spacing of 60 x 30 cm for higher seed yield and quality.

Keywords: Pak choi, Planting density, Seed quality, Seed yield

Pak choi (*Brassica rapa* L. subsp. *chinensis* L.) as a highly rated exotic leafy vegetable and an excellent food alternative, grown for its enlarged, edible, terminal buds; and is preferably eaten almost everywhere in the world [1]. It was made known around the world by the efforts of the travelers and immigrants [2-3]. Pak Choi: syn. *Brassica chinensis* L. (1759), *Brassica campestris* L. subsp. *chinensis* L.) Makino [4], *Brassica rapa* L. subsp. *chinensis* (L.) Hanelt [5] evolved in China, and its cultivation was recorded since the fifth century AD. It is widely grown in southern and central China, including Taiwan. This group is a relatively new comer vegetable in Japan where it is still referred to as 'Chinese vegetable' [6]. Being a leafy vegetable, Chinese cabbage possesses a short shelf life and therefore, it should be produced near the markets. The leaves of the crop can be consumed from transplant stage, but it is recommended to harvest rosettes after 50 to 60 DAS or 30 to 40 days DAT [7]. The crisp leaves and thick petioles of less bitter taste are excellent for cooking as a boiled vegetable [8]. Food nutrition is becoming one of the most important criteria in the choice of products in the modern era. *Brassica* vegetables are characterized by high water content, low caloric value, containing high quality of protein, carbohydrates, fiber, vitamins, minerals, and also secondary plant metabolites. Thus, they help in enhancing the immune system naturally and reduce inflammation in humans, due to anti-carcinogenic, antioxidant, antibacterial and antiviral properties. Nevertheless, *Brassicas* prevent the development of cardiovascular diseases and illnesses associated with ageing as well [9, 10]. This vegetable crop is gaining momentum in Indian sub-continent, because of increasing health awareness. This species can be possibly cultivated in winter in northern plains of India because of not having high thermal needs and possessing a rather short vegetation period and during spring season in the hilly areas. Almost all seeds being grown in the country are imported and a huge amount of money is being paid for that. Hence, attempts are being made at ICAR-Indian Agricultural Research Institute, New Delhi to develop a variety of Pak choi. The promising material, Pusa Pak choi-1 was developed and tested over locations.

The establishment of optimum population density per unit area is a prerequisite for realizing potential crop yields, as it influences yield and yield attributes of genus brassicas [11]. Rapeseed-mustard yield can be affected by competitive interaction among individual plants when they need a particular factor necessary for growth and development. It is well established that the crop environment with regard to light intensity and concentration of carbon dioxide can play a vital role in photosynthesis of the plant and thus increase dry matter accumulation and vegetative growth of the plant. Therefore, this study focused on the preliminary evaluation of Pusa Pak choi-1 for its seed production potential with reference to planting densities.

MATERIALS AND METHODS

The present investigation was conducted at Research Farm of CPCT/ Division of Seed Science and Technology, ICAR-IARI, New Delhi during *rabi* 2019-20. The experiment was conducted in Randomized Block Design (RBD) and four different plant spacing's of 60×45 cm, 60×30 cm, 45×30 cm and 30×30 cm were used to evaluate the effect on the growth and yield attributes of the crop. The intercultural operations such as weeding, rouging and chemical pest management were undertaken, as and when required. The irrigations were provided at 25 days and 45 days after sowing in order to maintain required moisture in the field. The maturity of crop was determined when 80-85% of pods became grey in color. Ten plants in each plot were randomly selected and tagged for recording number of branches per plant, number of silique per plant, number of silique per branch, number of seeds per silique at the time of harvest. An area of 1 m^2 was harvested from center of each plot and the seeds were threshed and Sun dried. The seeds were separated from the silique by beating with bamboo sticks and later cleaned, dried, weighed and expressed as t ha^{-1}. The different growth parameters studied were measured as initial plant population per hectare, plant height (cm), yield and yield attributes along with them some seed quality parameters were also studied.

RESULTS AND DISCUSSION

Effect of planting densities on seed yield and yield attributes

The analysis of preliminary data for the plant population, plant height, number of branches per plant and number of silique with respect to plant density indicated that planting densities had a significant effect on seed yield and yield attributes (Table 1 and 2).

Branches per plant

Plant densities had significant effect on number of branches $plant^{-1}$ at maturity. Spacing of 60 × 45 cm produced highest number of primary, secondary and tertiary branches $plant^{-1}$ i.e. 6.3, 9.1 and 8.2, respectively which was significantly higher than spacing of 60 × 30 cm, 45 × 30 cm and 30 × 30 cm (Table 1). The higher number of branches $plant^{-1}$ in 60 × 45 cm spacing were accounted for due to lesser competition amongst the plants and availability of sufficient light intensity as a potent source for enhanced crop biomass, in case of lower plant densities [12,13]. The same plant spacing also recorded greater plant height (88.8 cm), which was significantly higher than 60 × 30 cm, 45 × 30 cm and 30 × 30 cm i.e. 80.1, 75.3 and 65.5 cm, respectively (Table 1).

Table 1. Effect of plant spacing on plant height, plant population, number of branches and number of silique per plant during *rabi* 2019-20

Planting spacing (cm)	Plant height (cm)	Plant population/ha (approx.)	Number of branches per plant			Number of silique/ plant	
			Primary branches	Secondary branches	Tertiary branches	Secondary branches	Tertiary branches
60 × 45	88.8	37,037	6.3	9.1	8.2	110.4	45.2
60 × 30	80.1	55,555	5.5	8.3	7.1	102.5	43.7
45 × 30	75.3	74,074	3.4	6.5	3.3	89.1	26.2
30 × 30	65.5	1,11,111	2.7	4.3	3.1	75.6	25.4
SEm	1.13		0.24	0.20	0.21	1.36	1.15
CD (p=0.05)	3.45		0.59	0.54	0.61	4.23	3.24
C.V. (%)	10.34		10.10	10.58	10.73	11.40	8.73

Table 2. Preliminary data for yield and yield attributes during *rabi* 2019-20

Planting spacing (cm)	Number of seeds per silique	Seed yield per plant (g)	Seed yield per secondary branch (g)	Seed yield per tertiary branch (g)	Seed yield (t/ha)
60 × 45	26.5	45.1	37	8.1	1.67
60 × 30	24.1	38.5	31.2	7.3	2.14
45 × 30	18.3	18.3	13.7	4.6	1.36
30 × 30	12.7	8.9	6.20	2.7	0.98
SEm	0.81	1.09	0.43	0.32	0.21
CD (p=0.05)	0.41	2.29	1.12	1.31	0.42
C.V. (%)	9.87	8.73	9.4	10.12	10.31

Number of silique per plant

The number of silique per plant were also significantly affected by the plant densities (Table 1). Maximum number of silique per secondary and tertiary branches plant^{-1} i.e. 110.4 and 45.2, respectively were observed in the spacing of 60 × 45 cm, which was significantly higher than 60 × 30 cm, 45 × 30 cm and 30 × 30 cm spacing (Table 1) but there were no silique observed on primary branches. This was due to the variation in genetic makeup of different varieties, affecting number of siliqua plant^{-1}. Generally, lower plant population increased the number of siliqua plant^{-1} and vice versa [14, 15, 16]. This might be due to the reason that the number of silique, which were produced solely by an individual plant, tend decrease due to low space and more competition among the plants with an increase in planting density [17].

Number of seeds per silique

The number of seeds siliqua^{-1} contributes substantially towards the final seed yield. The number of seeds siliqua^{-1} differed significantly among different plant densities (Table 1). Highest number of seeds siliqua^{-1} (26.5) were obtained in the spacing of 60 x 45 cm, whereas 30 x 30 cm exhibited the lowest number of seeds siliqua^{-1} (12.7). Overall, plant growth, development and final stature influenced total seed setting. Generally, consistent increase in the number of seeds siliqua^{-1} was observed with an increase in row spacing [18]. Similarly, number of seeds siliqua^{-1} significantly reduced with the increase in population density of *Brassica campestris* L. [19].

Seed yield

The results revealed that plant densities had a significant effect on seed yield per plant and seed yield per hectare (Table 2). The comparison of means showed that the highest seed yield plant^{-1} was recorded in spacing of 60 × 45 cm (45.1 g), whereas lowest seed yield plant^{-1} (8.9 g) was observed in case of 30 × 30 cm spacing. Higher seed yield per hectare was found in 60 × 45 cm and 60 × 30 cm spacing i.e. 1.67 and 2.14 t/ha, respectively which was significantly higher than the spacing of 45 × 30 and 30 × 30 cm i.e. 1.36 and 0.98 t/ha, respectively. The highest seed yield was observed in 60 x 30 cm spacing due to at par yield per plant, 1000 seed weight and higher no of plant per unit area. This treatment facilitated maximum utilization of nutrients as wells as higher dry matter production, which ultimately resulted in enhanced seed yield [16]. Moreover, active solar radiation was effectively used for achieving maximum economic yields by creating higher green canopy area and least inter-plant competition [20, 21].

Effect of planting densities on seed quality parameters:

It was clearly evident from the analysis of preliminary data for seed quality attributes, such as 1000 seed weight and vigour indices that planting densities had a significant effect on seed quality of Pak choi although not much variation was observed amongst the planting densities with respect to seed germination (Table 3).

1000-seed weight

The 1000-seed weight is important determinant related to the magnitude of seed development and seed quality and it also determines the seed yield potential of a particular crop. The results revealed that the 1000-seed weight was significantly affected by plant density (Table 3). The spacing of 60 × 30 cm recorded the highest 1000 seed weight (1.81 gm), whereas the lowest (1.44 g) was found in case of 30 × 30 cm spacing. It was reported that higher 1000-seed weight of *Brassica campestris* L. was attained with wider plant spacing [22]. However, these results are in contradiction with the other reports who revealed that thousand seed weight is the most stable

Table 3. Preliminary data for seed quality attributes during *rabi* 2019-20

Planting Spacing	1000 seed weight (g)	Germination %	Seedling Vigour Index I	Seedling Vigour Index II
60 × 45	1.79	95	650	18.6
60 × 30	1.81	96	663	18.9
45 × 30	1.60	95	599	17.1
30 × 30	1.44	94	510	12.3
SEm	0.25	0.98	1.12	0.45
CD (p=0.05)	0.67	2.66	14.21	1.34
C.V. (%)	6.57	10.14	10.23	6.73

part of yield attributes, which is not affected by plant density [23].

Seedling vigour index I and II

Seedling vigour index I and II are important seed quality parameters which determine physiological and physical basis of potential seed lot performance in the field. High vigour seed lots has good storage potential and retains high germination potential during storage. The results revealed that seedling vigour index I and II were significantly affected by the plant density (Table 3). The spacing of 60 × 30 cm recorded the highest seedling vigour index I (663), whereas the lowest (510) was found in spacing of 30 × 30 cm spacing. Similar trend was observed in case of seedling vigour index II where the spacing of 60 × 30 cm recorded the highest seedling vigour index I (18.9), whereas the lowest (12.3) was found in spacing of 30 × 30 cm spacing. These results suggested that the seeds produced from spacing of 60 × 30 was more vigorous as compared to other planting densities probably because of better utilization of crop inputs and micro-environment, thus resulting in enhanced seed quality.

CONCLUSION

These preliminary studies suggested a significant influence of plant density on seed yield dynamics and seed quality of Pak choi. A better performance was observed in medium plant densities over higher and lower ones with respect to yield contributing attributes as well as seed quality. Thus, it can be concluded that Pak choi should be planted with a spacing of 60 x 30 cm for higher seed yield and quality.

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