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Effect of Seedling Density on Growth Characteristics of Cabbage (*Brassica oleracea* var. capitata) cv. kf-65 in Nursery

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A R T I C L E I N F O

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A B S T R A C T

Crop yield is largely influenced by the seedling quality and establishment. Seedling density is an important factor that plays a vital role in producing quality seedlings. Seedling growth characteristics of cabbage cv. kf-65 was evaluated at four inter row and intra row spacing: 0.5cm×1.0cm, 1.0cm×1.0cm, 1.5cm×1.5cm, and 2.0cm×2.0cm in the field of Institute of Agriculture and Animal Science, Lamjung Campus during September-October, 2018. Seed germination was 96% under a partially controlled germinator in the lab whereas mean germination in the field was found to be 62%. Treatments were laid out in Randomized Complete Block Design with five replications. Data was collected after 23 days using the destructive sampling method. Plant height, leaf number, leaf area, fresh shoot and root weight and % dry matter was recorded from five samples from each replication of every treatment. Plant population had a significant effect on plant leaf area, fresh shoot and root weight and % dry weight. The 2.0cm×2.0cm spacing had significantly higher leaf area (25.3cm^2), fresh shoot (1.33g) and root weight (0.06g). Dry weight % (23%) was significantly higher for 1.5cm×1.5cm spacing. The result indicates that wider spacing (≥ 2cm) was found to be favourable to obtaining robust and quality seedlings.

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Introduction

Cabbage (*Brassica oleracea* var. capitata L. 2n=18) is an herbaceous biennial plant of the family Brassicaceae or Cruciferae, cultivated for its dense leafy head (Dhaliwal, 2017). Cabbage is cultivated by direct seeding method or transplanting method. The transplanting method is preferred over direct seeded method. Compared to the transplanting method, direct seeded method has low stand establishment rate. Transplanting gives high seed use efficiency and has a competitive advantage against weeds due to size advantage (Kumar et al., 2008). Broadcasting method or line sowing is followed for seed sowing in seed bed. Uneven seed distribution, poor growth and damping off due to high density is frequently evident in broadcasted nursery bed (Tiwari, 2009).

In a nursery bed, varying competition stresses under various plant density is one of the most important factors determining quality of seedlings. Planting density has been found to be as important as other factors influencing plant growth (Agarwal et al., 2007). Competition associated with different density alters plant morphology in various ways. The density of plant can affect the dry matter accumulation, canopy architecture, light conversion efficiency and plant growth. The plant density effects number of leaves and leaf area, leaf formation and development in response to competition for available space for nutrient absorption which would influence plant vegetative growth and development (Alabi et al.,2014).

Due to the various expense and constraints in maintaining nursery space, transplant is grown in smaller and smaller cell volumes so that more transplants can be grown in the limited space available. However, higher seedling density can lead to thin lanky seedlings and higher susceptibility to damping off decreasing quality of seedling. Low quality seedling might exhibit morphological and physiological characteristics that impair their performance under field conditions. High density of seedling causes poor air circulation and increased humidity ultimately encourage damping-off. Damping-off may affect from 5 to 80% of the seedlings, thereby inducing heavy economic consequences for growers (Lamichhane et al., 2017). Need of constant use of the fungicide adds up to those consequences. Lowering seedbed density to optimum level results in more seedlings from a given amount of seed and can improve field survival and growth (Tanaka, 2012). Very low density in seedling bed reduces economic profitability by inefficient utilization of resources as transplant production is labour and capital-intensive job (Mahajanashetti, 2016). Effective use of limited space is also a matter of concern in low seedbed density. Optimum plant spacing should be maintained to exploit maximum natural resources, such as nutrients, sunlight, soil moisture etc., and to ensure satisfactory growth and proper use of land (Sarkar et al., 2002). For line sowing 5-7 cm between the line and 3-5 cm between the seeds has been recommended to maintain the seedling density (JICA & DADO, 2016). However, limited research work has been conducted to validate the spacing and determine suitable spacing in nursery bed and optimize the seedling density. Thus, the present investigation aims to generate valuable information about seedling spacing and its effect on morphological traits of seedling.

Materials and Methods

Description of Experiment

The experiment was conducted in the field and laboratory of Lamjung Campus, IAAS during the period of Sept-Oct, 2018. Gemination test was conducted in the laboratory using Hybrid F1 seed of cabbage cultivar kf-65 of 97% seed purity. The field work was conducted in Randomized Complete Block Design with five replications. The field Preparation was done a week before sowing. After the primary tillage of the field, field was levelled and pulverized manually. The field was solarized for 2 days to raise the temperature to 49 °C and drenched with systemic fungicide, SAAF, using concentration 5g/litre. The field was divided into three plots and raised to prepare seed bed. Topsoil was made fine with the help of hoe to aid the proper germination of the seedling. Cypermethrin (2ml/l) was sprayed 10 days after sowing to protect against insect

Four different spacings viz. 0.5cm×1cm (T1), 1cm×1cm (T2), 1.5cm×1.5cm (T3) and 2cm×2cm (T4) were maintained. Distance between treatment was 10cm and 5cm between the replication. Land was prepared by pulverization, solarization and drenching with the fungicide SAFF(5g/L). Three Nursery Bed of dimension $1m^2$ was prepared and raised by 15cm. Seed were sown on 30^{th} Sept using calibrated thread. Fifteen seeds were sown in a row per replication. Vermicompost was mixed with sand in 1:1 ratio and cover the seeds after placing in the rows. Nutrient management was done by applying 1.8kg FYM, 5.24g of Urea, 8.60g of DAP and 4.95g of MOP per plot which was incorporated into the soil as a basal dose at a dose of 40:40:30kg NPK/ hectare.

Data Collection and Analysis

Data was collected after 23 days using destructive sampling method. Five samples were collected per replication. Parameters measured were plant height, root length, number of leaves, leaf area, fresh shoot and root weight and dry matter percentage. Leaves were separated, unfolded leaves were counted and photos were clicked for area analysis. Image J software was used for analysis of leaf area (Neal et al., 2002). It is image processing program developed by National Institute of Health, USA. More than 200 leaves form 100 seedlings were used to determine the leaf area. Leaves were placed in white paper and photographed. Plant height and root length of the seedlings were measured using ruler. Plant height was measured from collar region to the growing tip and root length was measured below the collar region. Fresh weight of shoot and root (FWSR) was measured using an electronic weighing balance after packing inside the envelope. It was calculated as:

$$\text{FWSR} = \frac{\text{total weight of shoot}}{(\text{root and envelope} - \text{ weight of envelope})}$$

Dry matter (DM) percentage was calculated by drying fresh sample for about 48 hours at 65°C embedded in an envelope. Then it was calculated by using the formula:

$$\text{DM} = \frac{\text{weight of dry sample}}{\text{weight of fresh sample}} \times 100$$

Dry Matter % = (weight of dry sample ÷ weight of fresh sample) × 100%

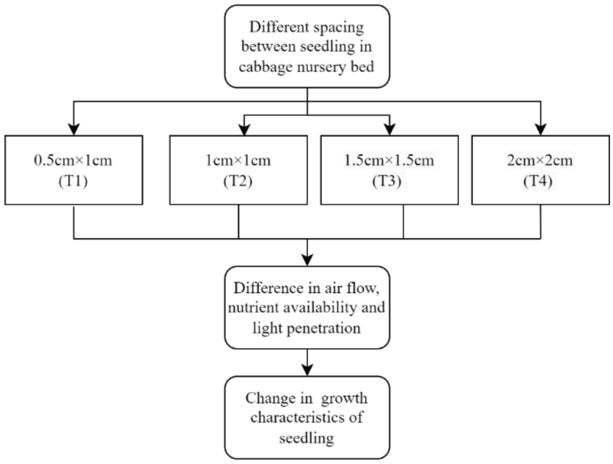

Figure 1. Diagrammatic framework of the study

Seed germination of seedlings was observed and recorded till 12 DAS. Statistical data analysis was done using Microsoft Excel and Gentat (15^{th} edition). Least significant difference was used to separate means at 5% probability level using Duncan's Multiple Range Test.

Results and Discussion

Effect of seedling density was observed in leaf area, shoot fresh weight, root fresh weight and % dry weight. Leaf area increased gradually with the increase in seedling spacing (Table 1). Similar trend can be observed in shoot and root fresh weight except for % dry weight where lower spacing has highest % dry weight (Table 2). Plant height, root length and no. of leaves remain unaffected by the density (Table 1).

Germination

Germination of seeds was observed in controlled laboratory environment and field condition. Seed germinated vigorously with higher germination percentage (96%) in the laboratory. However, in field, such vigour was not observed. Mean germination percentage was 62% in field condition. Treatment 1.5cm×1.5cm had highest germination (73%) whereas treatment 1.0cm×1.0cm had lowest germination (39%). Optimum growing environment created in lab artificially boosted the germination. However, in field condition infestation of damping off, fluctuating temperature and variable moisture regime decreased the seed germination.

Table 1. Effect of seedling density in morphological traits of cabbage seedlings at nursery in field of Lamjung Campus, IAAS.

Density (cm^2)	Plant height (cm)	Root length (cm)	Leaves (No.)	Leaf area (cm^2)
0.5×1.0	6.72	3.98	2.20	11.88[b]
1.0×1.0	6.42	4.13	2.76	15.60[b]
1.5×1.5	6.13	4.18	2.96	17.68[b]
2.0×2.0	6.11	4.88	2.99	25.30[a]
F-test (α=0.05)	NS	NS	NS	*
SEM (±)	0.39	0.30	0.14	2.00
LSD	1.22	1.00	0.43	6.23
CV%	14	17	13.1	25.3

* = Significant(α=0.05), ** = Highly significant(α=0.01), NS= Non-significant, LSD = Least Significant Difference, CV=coefficient of variation, SEM = standard error of means. Mean(s) in the table followed by same letter(s) are not significantly different.

Table 2. Effect of seedling density on fresh shoot weight, root weight and % dry weight of cabbage seedlings at nursery in field of Lamjung Campus, IAAS.

Treatment	Fresh shoot weight (g)	Fresh root weight (g)	% dry weight
0.5×1.0	0.68c	0.02[c]	22[a]
1.0×1.0	0.88[bc]	0.02[bc]	19[a]
1.5×1.5	1.04[b]	0.03[b]	23[a]
2.0×2.0	1.33[a]	0.06[a]	9[b]
F test (α =0.05)	*	**	**
SEM (±)	0.08	0.01	0.01
LSD	0.26	0.01	0.04
CV%	19.1	30.6	17.1

* = Significant(α=0.05), ** = Highly significant(α=0.01), LSD = Least significant Difference, CV=coefficient of variation, SEM = standard error of means. Mean(s) in the column followed by same letter(s) are not significantly different.

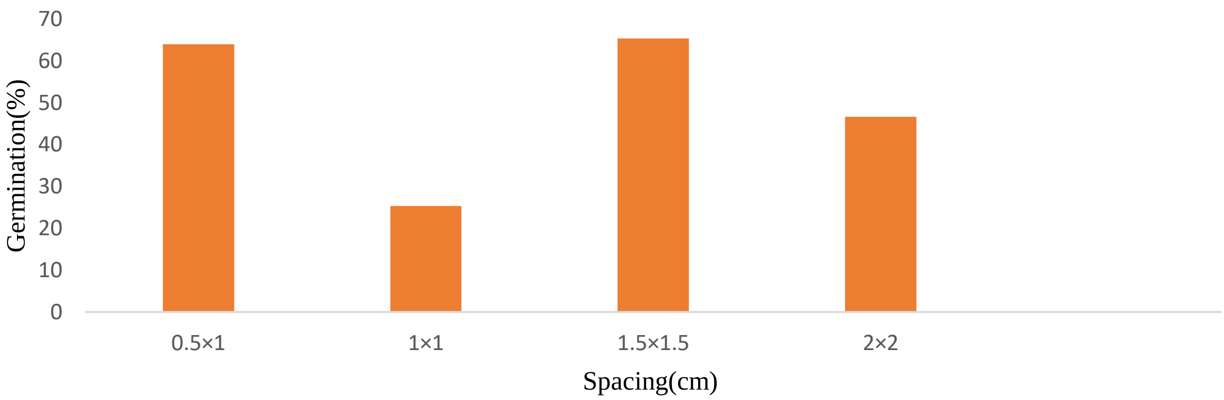

Figure1. Germination of cabbage seeds at 4 DAS in nursery bed of Lamjung Campus

Root Length

Root length of the seedlings were found to be non-significant among the different treatment. Longest root was found at seedling spacing 2.0cm×2.0cm (4.88cm) and shortest root length was found at treatment 0.5cm×0.5cm (3.98 cm). The result contradicts with Rajesh et al. (2017) and Khan et al. (2016) who reported longer root in lower seedling density. Lower level of ABA, which is responsible for root cell elongation and division, inhibits the root growth in well -watered condition (Harris, 2015). No water stress and proper nutrient management might have resulted in similar root growth.

Plant Height

There was no effect of the spacing treatment in the height of seedlings. Longest plant height was found at seedling spacing 0.5cm×0.5cm (6.72 cm) and shortest plant height was found at spacing 2.0cm×2.0cm (6.11cm). The result is in the line with the result obtained by Sarker et al. (2002) and Ullah et al. (2013) but contradicts with Turbin et al. (2014) who reported taller plants in wider spacing and Islam et al. (2011) observed tallest plant in lower spacing.

Number of Leaves

Seedling density had no significant effect on number of leaves. Highest number of leaves were found at seedling spacing 2.0cm×2.0cm (2.99) and lowest number of leaves were found at seedling spacing 0.5cm×0.5cm (2.52). The result is supported by Essifile et al. (2017) and Ahamad et al. (2007) but contradicts with Moniruzzman (2006) and Islam et al. (2011) who reported higher no of leaves in wider spacing.

Leaf Area

Leaf area was found to increase significantly with the increase in spacing. The lowest leaf area was observed at 0.5cm×0.5cm (11.88cm^2) spacing treatment which was statistically at par with the treatment 1.5cm×1.5cm ($17.68cm^2$) and 1.0cm ×1.0cm ($15.6cm^2$). Highest leaf area was observed for the treatment 2.0cm×2.0cm (25.53 cm^2). Higher leaf area in wider spacing treatment may be due to increased investment in leaf portion i.e. higher nutrients, moisture absorption and space availability for spreading (Johnson and William, 1997).

Koike (1989) states that growth is due to utilization of greater resources. Light is one of the abundant resources in the wider spacing. Sunlit portion grows more due to higher local carbon fixation (Ford, 2014). So, in lower spacing higher competition for light in small region and shading due to neighbour plant would supress growth of leaf. But in wider spacing increasing in leaf growth would be optimal strategy for the plant to increase the light interception and acquire higher radiation utilization efficiency (Irving, 2015; Weraduwage et al., 2015).

Fresh Shoot and Root Weight

Fresh shoot and root weight increased significantly with increase spacing. The data observed for fresh shoot weight showed that lowest weight was found at spacing 0.5cm×1cm (0.67g) Highest shoot weight was found at spacing 2.0cm×2.0cm (1.34g) followed by 1.5cm ×1.5cm (1.04g) and 1.0cm ×1.0cm (0.88g) respectively. Highest root weight was observed at 2cm ×2cm (0.057 g). Root weight of 1.5cm ×1.5cm (0.03g) was at statistically par with 1.0cm×1.0cm.

Larger leaf area, low competition for the nutrients and space, higher light penetration and well-developed root system for absorption of the nutrients may have caused for higher fresh weight at wider spacing (Sarkar et al.,2013). Leaf area determines interception of Photosynthetically Active Radiation (PAR) and Radiation use Efficiency (RUE) which is directly correlated with biomass yield in most crops (Gardener et al., 2017). Increase in leaf area with spacing contributed to increase in fresh shoot and root weight. Rate of evapotranspiration also increases with increase in leaf area (Nadi, 1974). Thus, moisture content tends to increase in seedlings adding to its fresh weight. Lower spacing increases mutual plant shading which causes depression in photosynthesis and greater competition for water and nutrients lowering the weight (Marchiori et al., 2014).

Dry Matter Accumulation

The treatment had significant effect on the Dry matter accumulation. In contrast to Fresh weight, lowest % dry weight was observed for the treatment 2.0cm ×2.0cm (9%). Highest % dry weight was found at treatment 1.5cm×1.5cm (23%) followed by 0.5cm×1cm (22%) and 1.0cm×1.0cm (19%).

Higher seed sowing density may result in a more stable micro-environment with a reduction in fluctuations in temperature and relative humidity, the resulting environment favouring the germination and establishment of seedlings (Waite and Hutchings, 1978). Uneven moisture distribution during irrigation might also lead to higher moisture in those treatments. Seed germination is higher in higher soil moisture content than at lower soil moisture content (Donnen and Macgillivray, 1943).

Variation in the time of seedling emergence has a large effect on the size of individual plants and this intern greatly influences the outcome of the subsequent competition between individuals for growth resources (Shanmugnathan and Benjamin, 1993). The plants mass has been found to have positive correlation with the emergence. Late emerging plants have lower plant mass at harvest (Goldberg and Linda, 1991). The rapid vegetative growth due to early germination resulted in the ability to more efficiently absorb diffused radiation which increased the dry matter (Buriol et al., 1995).

Conclusion

The findings of the experiment show that the higher spacing (≥ 2cm) i.e., lower seedling density is imperative to obtain superior seedling characteristics. Increase in plant fresh weight and leaf area in wider spacing due to reduced interplant competition for nutrients, moisture, air and space, higher light penetration, less mutual shading and less root binding is evident. Seedling of Cole crops are grown in nursery bed in most of the small farms and nurseries. The research shed light on seedling spacing required on seed bed. As growing more seedlings per unit area translates to higher profitability from seedling business considering all input and labor cost, results obtained can be valuable for the farmers. However, research has been conducted using locally available tools and techniques. Thus for proper recommendation further research and trials using precise microtools with various spacing options is required to determine physical and physiological effect of seed spacing.

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