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Effect of Seedling Density on Morphological Attributes of Cabbage, Cauliflower and Broccoli under Protected Condition

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Abstract- One of the most crucial and substantial factor in any of the crop for its triumph, seedling quality remains the foremost position which can be enhanced by its density resulting in the robustness, ultimately increasing the overall performance of vegetable crop. Nevertheless, their densities give rise to the vigor one influencing their survival and early establishment, being the major consideration affecting the growth and health of seedling further influencing the crop productivity. Therefore, an experiment was carried out to identify the optimum seedling density and study their effect on different morphological attributes of Broccoli cv. Green Pia, Cabbage var. Green Top and Cauliflower var. Snow Mystique in both lab and field conditions. The research design was Randomized Complete Block Design with four treatments viz. 0.5cm × 1.0cm (T1), 1.0cm × 1.0cm (T2), 1.5cm × 1.5cm (T3), and 2.0cm × 2.0cm (T4) replicated five times. Destructive sampling was done after 23 days of seed sowing to study the growth attributes viz. plant height, number of leaf, leaf area, root length, root fresh weight, shoot fresh weight, shoot dry weight and dry weight percentage. Software image J was used to measure leaf area, MS-Excel for data tabulation which were analyzed by using GenStat 15th Ed. Germination percentage was 84%, 86%, 88.0% in lab while seedling establishment was 53%, 66.3%, 70.3% in nursery bed respectively for Cabbage, Cauliflower and Broccoli.

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Effect of Seedling Density on Morphological Attributes of Cabbage, Cauliflower and Broccoli under Protected Condition

B. Thapa [α], P. Pandey [σ], S. Paudel [ρ], K.C. Dahal [Ѡ], A. Khanal [¥] & A. Shrestha [§]

Abstract- One of the most crucial and substantial factor in any of the crop for its triumph, seedling quality remains the foremost position which can be enhanced by its density resulting in the robustness, ultimately increasing the overall performance of vegetable crop. Nevertheless, their densities give rise to the vigor one influencing their survival and early establishment, being the major consideration affecting the growth and health of seedling further influencing the crop productivity. Therefore, an experiment was carried out to identify the optimum seedling density and study their effect on different morphological attributes of Broccoli cv. Green Pia, Cabbage var. Green Top and Cauliflower var. Snow Mystique in both lab and field conditions. The research design was Randomized Complete Block Design with four treatments viz. 0.5cm × 1.0cm (T1), 1.0cm × 1.0cm (T2), 1.5cm × 1.5cm (T3), and 2.0cm × 2.0cm (T4) replicated five times. Destructive sampling was done after 23 days of seed sowing to study the growth attributes viz. plant height, number of leaf, leaf area, root length, root fresh weight, shoot fresh weight, shoot dry weight and dry weight percentage. Software image J was used to measure leaf area, MS-Excel for data tabulation which were analyzed by using GenStat 15th Ed. Germination percentage was 84%, 86%, 88.0% in lab while seedling establishment was 53%, 66.3%, 70.3% in nursery bed respectively for Cabbage, Cauliflower and Broccoli. Significantly longer root length (4.83 cm) was obtained in 2.0cm×2.0cm which was at par with spacing 1.5cm×1.5cm whereas shorter root length (3.62cm) was obtained in 0.5cm×1.0cm. Similar trend was obtained in number of true leaves and leaf area. Similarly, significantly higher root length (4.93 cm), shoot fresh weight (1.03 g), shoot dry weight (0.09 g),leaf number(1.91) and leaf area (14.85 cm^2) were obtained in 2.0cm×2.0cm for Cauliflower whereas, in the seedlings of Broccoli root length was found significantly higher in the treatment 2.0cm × 2.0cm whereas lower in 1.0cm × 1.0cm which was at par with other treatments. Similarly, leaf area in the treatment 2.0cm × 2.0cm was significantly higher while lowest in 0.5cm × 0.5cm whereas other treatments were at par. For proper seedling production and establishment wider spacing was found superior over narrow spacing.

I. Introduction

Considering the economy, better production and productivity plays the vital role, however poor seedling quality and management practices constrains them. The most important factors contributing towards high productivity of any crop is quality planting material as worthiness of a farmer's effort depends on the good quality of planting material to transfer seedling in the main field (Ferguson *et al.,* 1991). Along with various climatic and edaphic conditions, seedling density is one of the important factors that determine the health of the seedlings in the nursery bed. A vegetable nursery must ensures proper establishment for raising or handling of young vegetable seedlings until they are ready for permanent planting as it was reported that 20% of total production depends on good quality seeds which can be extended up to 45% by efficient nursery management (Feijter, 2015). Plant density is an important agronomic factor and the chosen crop spacing must be based on the hypothesis that optimal PPD allows interception of all (≥95%) of the available photosynthetically active radiation (Duncan, 1986; Purcell *et al*., 2002).

The two distinct phases in the life cycle of the plants: seed to emergent seedlings; and emergent seedlings to established plants; where former phase includes the process of emergence, with the end product being density of seedlings, and the later phase includes survival and growth rate, with the end products being density and dry weight of survivors. Increasing seed density decreased the probability of a seedling emerging, while measures of growth or survival at later life stages were unaffected by the initial seed density (Callaway & Walker 1997; Holmgren *et al*. 1997).

The present research is thus carried out to investigate the effect of seed spacing on the robustness, health and growth of seedling of members of the Cole crops *i.e.* Cabbage, Cauliflower and Broccoli as good estimation of seed rate to produce the maximum number of quality seedling is the next problem faced by the farmers. This study elucidates the best method for quality seedling production and vegetables to find out the best one for the recommendation to the extension worker, vegetable growers, seed and seedling growers, besides unemployed youth and other stakeholders who intend to make vegetable seedling production as a business and the farming community as a whole directly and indirectly.

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II. Materials and Methodology

The study was carried out at Horticultural Research lab and farm of Institute of Agriculture and Animal Science (IAAS), Lamjung Campus, Tribhuvan University during the autumn season of 2018. Germination % was calculated in lab along with determination of different physical characteristics of seed viz. colour, diameter, shape, test weight and purity% whereas seedling establishment % was assessed in nursery bed. The experiment was laid out in single factor Randomized Complete Block design (RCBD) with four treatments viz. 0.5 × 1.0 (cm^2), 1.0 × 1.0 (cm^2), 1.5 × 1.5 (cm^2) and 2.0 × 2.0 (cm^2)replicated five times. Field was prepared on the month of the September with the help of spade followed by land leveling, drenching with the fungicide named SAAF which was then solarized. After the solarization of bed for three days, the seeds of the Cauliflower var. Snow Mystique, Cabbage var. Green top and Broccoli car. Green Pia was sown on the line with the same spacing mentioned in the treatment. Recommended doses of NPK and vermicompost were applied (5.34g Urea, 8.60g DAP, 4.95g MOP and 1.8 kg vermicompost for the area of 0.99m^2) as a source of fertilizer. Cypermethrin as a plant protection was broadcasted in the bed after the fourth days of seed sowing. Mulching was done and irrigation was done whenever necessary. Germination and establishment of seedling were thoroughly observed for 12 days and after the 23rd days, destructive sampling method was carried out for further observation. Data were recorded for plant height, root length, leaf number, its area, LAI and root and shoot biomass. A software tool called ImageJ was used for assessing leaf area. ImageJ is a java based image processing program used to measure area via pixel counting of the image. Obtained data were entered using MS- Excel (2010), analyzed statistically using Genstat 15th edition at 5% level of significance and were interpreted using MS-Word (2010).

III. Results and Discussions

a) Germination% and Seedling establishment%

The germination test revealed 84%, 86% and 88% germination of Cabbage, Cauliflower and Broccoli respectively in lab whereas seedling establishment was found to be 53%, 66.33% and 70.33% in field condition on the12th day of seed sowing. However, the reason for the reduction of the seedling establishment in field after the germination was due to the problem of damping off and insect cutting.

b) Effect of seedling density on plant height (cm), root length (cm), leaf area (cm^2), number of leaves, fresh weight of both root and shoot (g), dry weight of shoot (g) and dry weight percentage of Cabbage var. Green Top, Cauliflower var. Snow Mystique and Broccoli c.v. Green Pia

The table below represents effect of seedling density on plant height (cm), root length (cm), leaf area (cm^2), number of leaves, fresh weight of both root and shoot (g), dry weight of shoot (g) and dry weight percentage of Cabbage, Cauliflower and Broccoli seedling.

A. Effect of seedling density on Cabbagec.v. Green Top

i. Plant height(cm)

There was no significant effect of seedling density on plant height. Similar, result was found by (Mohamed, 2002) who reported that plant population had no significant effect on plant height on cowpea.

ii. Root length(cm)

Spacing had significant effect on the root length. 2.0cm×2.0cm produced the longest root length(4.83cm) which was statistically at par with 1.5cm×1.5cm. Shortest root length (3.62 cm) was noted in 0.5cm×1.0cm which was statistically at par with 1.0cm×1.0cm.1.0cm×1.0cm and 1.5cm×1.5cm were statistically at par with each other. 2.0cm×2.0cm produced significantly superior root length to 0.5cm×1.0cm and 1.0cm×1.0cm. With increasing plant density, light interception per plant decreases, resulting in a reduction in whole-plant photosynthesis and biomass accumulation. Therefore, carbon allocated to the roots can be greatly reduced and the total length of the roots is reduced under high plant density and increase in low plant density. Minami and Sirkar reveal the same results regarding root length, by increasing plant to plant spacing increases root length. The findings of Chatterjee and Som also have the similar results.

iii. Number of true leaves

Significant result was recorded for number of true leaf area. Highest no of leaf (3.20) was found in 2.0cm×2.0cm which was statistically at par with 1.5cm×1.5cm. The least amount of leaf (2.61) was found in treatment 0.5cm×1.0cm which was statistically at par with 1.0cm×1.0cm and 1.5cm×1.5cm. 2.0cm×2.0cm was significantly superior to 0.5cm×1.0cm and 1.0cm×1.0cm. In wider spacing there is less competition for nutrients, moisture and light among the plants to achieve the required food for their growth and plants that receive more light tend to have more leaves (Milthorpe and Mourby, 1979). (Kathirvelan and Kalaiselvan, 2007) observed that there could be more feeding zone which encourages lateral growth resulting in the production of more branches and leaves

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per plant. These results are in agreement with the previous findings by (Alege and Mustapha, 2007). Same results are confirmed by the findings of Shrivastava that as we increase the spacing between two plants, there will be a significant increase occur in number of leaves.

iv. *Leaf area(cm^2)*

There was significant effect of seedling density in leaf area. Maximum leaf area (22.28 cm^2) was found in the treatment 2.0cm×2.0cm which was statistically at par with 1.5cm×1.5cm. Minimum leaf area (10.28 cm^2) was found in treatment 0.5cm×1.0cm which was statistically at par with 1.0cm×1.0cm and 1.5cm×1.5cm. 2.0cm×2.0cm was superior to 0.5cm×1.0cm and 1.0cm×1.0cm. Difference in leaf area by variable plant spacing might be due to the favorable environmental conditions leads to increase in leaf size. Results are in conformity with the finding of (Cebula *et al*., 1994) in white cabbage. It lines with the finding of (singh and singh 2000) who stated that the maximum number of leaves were noted at wider spacing.

v. *Fresh weight root(g)*

Significant results were recorded for root fresh weight. 2.0 cm×2.0cm produced the maximum fresh weight (0.055 g). Minimum fresh weight (0.025g) was noted in 0.5cm×1.0 cm which was statistically at par with 1.0cm×1.0cm and 1.5cm×1.5cm. 2.0 cm×2.0cm was superior to 0.5cm×1.0 cm, 1.0cm×1.0cm and 1.5cm×1.5cm. The wider spacing provided more chance for development of root by proper utilization of assimilate which resulted in a maximum root weight (Hussain *et al*, 2008). Similar results were obtained in onion by (Khushk *et al*.,1990) and in radish by (Pervaz *et al*.,2004).

vi. *Shoot dry weight(g)*

Significant results were recorded for the shoot dry weight. 2.0 cm×2.0cm produced the highest dry weight (0.090g) which was statistically at par with 1.0cm×1.0cm and 1.5cm×1.5cm. Lowest dry weight (0.035 g) was noted in 0.5cm×1.0 cm which was statistically at par with1.0cm×1.0cm and 1.5cm×1.5cm. 1.0cm×1.0cm and 1.5cm×1.5cm were also at par with each other. Dry weight is a net result of photosynthesis activities thoroughly. Sunlight is a major factor in the photosynthesis process, the more sunlight it receives, the photosynthesis process can run well, resulting in more photosynthate made. Larger photosynthetic production will form larger plant organs which those affecting the increase of dry weight of plants.

Table 1: Effect of seedling density in morphological character of Cabbage in Lamjung in 2018

Treatment (cm^2)	Plant height (cm)	Root length (cm)	Leaf area (cm^2)	No. of leaves	Root FW(g)	Shoot FW (g)	Shoot DW (g)	DW %
0.5 × 1.0	6.72	3.62^c	10.28^b	2.61^b	0.025^b	0.621	0.035^b	5.979
1.0 × 1.0	5.89	3.81^{bc}	12.72^b	2.65^b	0.036^b	0.688	0.060^{ab}	7.296
1.5 × 1.5	5.99	4.58^{ab}	14.01^{ab}	3.00^{ab}	0.039^b	0.804	0.065^{ab}	7.840
2.0 × 2.0	6.27	4.83^a	22.28^a	3.20^a	0.055^a	1.143	0.090^a	8.555
Grand mean	6.22	4.21	14.8	2.86	0.039	0.815	0.063	7.42
F test(α=0.05)	NS	*	*	*	*	NS	*	NS
CV %	13.5	15.6	41.1	11.5	29.5	37	37.5	44.4
LSD	1.15	0.90	8.40	0.45	0.0159	0.414	0.0325	4.539

*NS non-significant, * significant at 5% and **highly significant at 1%,*

Values within the same column with a common alphabet are not significantly different

B. *Effect of seedling density on Cauliflower c.v. Snow Mystique*

i. *Plant height(cm)*

There was no significant difference in plant height among the seedling obtained from various treatments. On contrary to this result, some of the research findings revealed the increase in plant height whereas some revealed the decrease in plant height with increment in the plant density. Qodliyati*et.al* (2018) in his experiment in Cassava found out the increase in plant height in wider spacing. The reason he stated was that the wider planting space will increase the availability of nutrients and water for individual plants so that the growth of the plant increases. These findings are in close conformity with the findings of Rahman*et.al*. in cauliflower, Saikia*et al.* (2010) in broccoli also. However, Tejaswini*et.al* (2018) in his experiment in broccoli found out the increase in plant height in narrow spacing. This might be due to more terminal increase than later growth and mutual shading in closer spaced plants.

ii. *Root length(cm)*

The effect of seedling density on root length was found to be highly significant. Longer root length (4.928 cm) was obtained in wider spacing of 2.0cm×2.0cm.And significantly shorter root length(3.676 cm) was obtained in the spacing of 1.5cm×1.5cm which was found to be statistically at par with the treatments of spacing of 1.0cm×1.0cm and 0.5cm×1.0cm. This

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finding is in close conformity with the research of Amjad and Anzum (2001) in carrot plant. And the reason could be more availability of moisture in the case of higher spacing that cause higher proliferation of the root leading to longer root length.

iii. *Number of true leaves*

The effect of seedling density on number of true leaves was found to be significant. Significantly more number of true leaves (2.720) was obtained in wider spacing of 2.0cm×2.0cm which was found to be statistically at par with the treatment of 1.5cm×1.5cm and 1.0cm×1.0cm whereas significantly less number of true leaves (1.910) was obtained in spacing of 0.5cm×1.0cm which was also found to be statistically at par with the treatment of 1.0cm×1.0cm. Moniruzzaman (2011) in hybrid cabbage and also Chiluwal*et.al* (2018) in cane plant obtained the similar result in his experiment where wider spacing showed higher number of leaves. The reason for higher number of leaves in case of lower seedling density might be due to the lesser competition for nutrients and light among the plants. Enhanced light interception due to wider spacing certainly had a positive effect on leaf number. Hence in wider spacing due to availability of more space and light, the crop might have pronounced more number of leaves per plant.

iv. *Leaf area(cm^2)*

Result showed significant differences for the leaf area of seedlings under various treatments. Significantly larger leaf area (14.850 cm^2) was obtained in the spacing of 2.0cm×2.0cm which was at par with the spacing of 1.5cm×1.5cm and 1.0cm×1.0cm whereas significantly smaller leaf area (5.600 cm^2) was obtained in the spacing of 0.5cm×1.0cm which was also at par with the spacing of 1.5cm×1.5cm and 1.0cm×1.0cm.More number of leaf was observed in wider spacing which might be contributing for more leaf area. Streck*et.al* (2014) found the result in close accordance with this result where minimum leaf area was observed in narrower spacing. In narrow spacing, water stress is seen, and there might be the decline in the cell enlargement resulting from reduced turgor pressure which cause the reduction in the leaf area (Shao *et al.,* 2008).

v. *Shoot fresh weight(g)*

Data concerning this parameter were subjected to statistical analysis and result showed significant differences for the fresh weight of shoot. Maximum fresh weight (1.030g) was obtained in spacing of 2.0cm×2.0cm and minimum fresh weight (0.400g) was found in the treatment of 0.5cm×0.5cm which was found to be statistically at par with the treatment of 1.0cm×1.0cm. Wider spacing allows for the growth of the lateral branches contributing to the higher fresh weight of shoot. More light interception will enhance the photosynthesis process in wider spacing which will ultimately increase the fresh weight of shoot. Qodliyati and Nyoto(2018) in their research in arrowplant also found the similar result in case of arrow plant. And in case of narrow spacing reduction in fresh weight of shoot is due to decrease in photosynthesis and canopy structure during the water and nutrient stress (Bahreininejad *et.al*.,2013).

vi. *Root fresh weight(g)*

Analysis showed non-significant result in case of fresh weight of root between the treatments. And in contrast with this result Ali et.al (2018) in turnip, Khusk*et.al* (1990) and Pervaz*et.al* (2004) in radish obtained the higher fresh weight of root in the case of wider spacing. The length of the root gets increased with increase in spacing which allows for the accumulation of higher photosynthate and ultimately the fresh weight of the root gets increased. And in case of narrow spacing there will be lower availability of the moisture around the root due to the competition and thus a lesser proliferation of root biomass resulting in the lower absorption of nutrients and water leading to production of lower biomass (Singh *et al*.1997).

vii. *Shoot dry weight(g)*

The result showed significant effect on dry weight of shoot among various treatments. Highest dry weight of shoot (0.095g) was obtained in wider spacing of 2.0cm×2.0cm which was found to be statistically at par with the spacing of 1.5cm×1.5cm and the lowest dry weight of shoot (0.031g) was found in the narrow spacing of 0.5cm×0.5cm which was statistically at par with the spacing of 1.0cm×1.0cm. The reason behind the higher dry weight of shoot in wider spacing could be the more accumulation of the photosynthate in case of the wider spacing. Dry weight is the net result of photosynthesis activities. And the major factor in the photosynthesis process is the sunlight, the more sunlight it receives, the photosynthesis process can run well, resulting in more photosynthate. And the seedling could receive more sunlight in the case of wider spacing in comparison with the narrow one. And this larger photosynthetic production will increase the dry weight of the shoot. Similar result is obtained in the research of arrow plant. (Qodliyati and Nyoto, 2018).

viii. *Dry weight %*

Data concerning this parameter were subjected to statistical analysis and result showed non-significant result for the dry weight %. Dry weight% depends upon both the dry and fresh weight of the plant. Actually dry weight % is the ratio of fresh weight to the dry weight multiplied by 100.

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Table 2: Effect of seedling density in morphological character of Cauliflower in Lamjung in 2018

Treatment (cm^2)	Plant height (cm)	Root length (cm)	Leaf area (cm^2)	No. of leaves	Root FW(g)	Shoot FW (g)	Shoot DW (g)	DW %
0.5 × 1.0	6.70	3.78^{b}	5.60^{b}	1.91^{b}	0.017	0.40^{c}	0.031^{c}	7.57
1.0 × 1.0	6.74	3.57^{b}	10.58^{ab}	2.39^{ab}	0.021	0.65^{bc}	0.061^{bc}	10.08
1.5 × 1.5	6.58	3.68^{b}	10.84^{ab}	2.44^{a}	0.025	0.73^{b}	0.066^{ab}	9.06
2.0 × 2.0	6.29	4.93^{a}	14.85^{a}	2.72^{a}	0.040	1.03^{a}	0.095^{a}	9.11
Grand mean	6.58	3.99	10.47	2.36	0.026	0.70	0.0631	8.95
LSD (0.05)	1.16	0.41	5.595	0.49	0.0172	0.29	0.0304	2.18
Significance Level	NS	**	*	*	NS	*	*	NS
CV%	13.1%	7.50%	38.80%	14.90%	47.90%	30.70%	35.00%	17.70%

*NS non-significant, * significant at 5% and **highly significant at 1%,*
Values within the same column with a common alphabet are not significantly different

C. *Effect of seedling density on Broccoli c.v. Green Pia*

i. *Plant height(cm)*

It was significantly higher (9.08cm) in higher density (0.5cm×1cm) over other treatments whereas, seedlings in the spacing 1.0cm×1.0cm, 1.5cm×1.5cm and 2.0cm×2.0cm were found statistically at par in terms of its height. Seeds that are planted too close to one another are known to grow taller initially to compete for sunlight. The increase in plant height at higher PPD is probably caused through stem elongation (*Reddy et al.*, 1999; Pendersen and Lauer, 2003) and increase of number of nodes per plant (Oh *et al.*, 2007) due to mutual shading (Dominguez and Hume, 1978), while decrease of plant height above the optimal PPD is caused by inter plant competition for growth factors such as moisture, light and nutrients (Chanprasert, 1988).

ii. *Root length(cm)*

The effect of seedling density on root length shows that the value of the root length (5.20cm) was significantly higher in wider spacing i.e. 2.0cm × 2.0cm. Further, results in the remaining treatment were found statistically at par to each other indicating there was no any difference in choosing the spacing of 0.5cm × 1.0cm, 1.0cm × 1.0cm and 1.5cm × 1.5cm having the value 4.32cm, 4.32cm and 4.45cm respectively. A marked increase in root length was found at wider plant spacing. Bidel *et al.,* (2000) quoted that less carbohydrate in plant means shortened number, length and diameter of roots. For a given investment of carbohydrate, seedling at higher density expends more for its stem elongation to fulfill its light requirements while, seedlings with the same amount of carbohydrates utilize it for root and shoot developmental characteristics.

iii. *Leaf area(cm^2)*

The results showed that leaf area in the wider spacing (2.0cm × 2.0cm) was significantly superior over narrow spacing having the value of 40.36cm^2 but significantly inferior value was obtained in the treatment 0.5cm × 1.0cm whereas, treatments 1.0cm × 1.0cm and 1.5cm × 1.5cm were significantly at par with the value 28.43cm^2 and 26.00cm^2 respectively. Leaf photosynthetic rate of plants grown under shaded conditions is lower than that of plants grown under conditions of full light, whereas the stomatal resistance to CO_2 diffusion is higher in relation to full light (Irmak *et al.,* 2008; Patakas *et al.*, 2003). Thus, lower photosynthetic activity means lower assimilates within plant leaf resulting small leaf with less leaf area.

iv. *Root fresh weight(g)*

The obtained result shows that highest fresh weight of root was found in 2.0cm × 2.0cm and 1.0cm ×1.0cm spacing having the value highest in former treatment (0.08g) followed by latter one (0.07g). Similarly, seedlings in treatment 0.5cm × 0.5cm cause lowest root fresh weight with the value of 0.05g. Moreover, in the treatment 1.5cm ×1.5cm, root fresh weight of the seedlings was statistically at par with the above treatments having the value of 0.06g. Root fresh weight is governed by three major factors viz. relationship between diameter and elongation attributes, topological connections of roots of different diameters and branching density of roots (Gretchen and Park, 1991). Root length is higher in plant with sparse density due to the availability of more carbohydrates needed for root development (Bidel *et al*., 2000) while root diameter is influenced by hydraulic, nutritional constraints and temporal variations in assimilate availability (Gretchen and Park, 1991; Thaler and Pages, 1996).

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v. *Dry weight %*

The results in the table 3, shows that dry weight % of the seedlings in the treatment 1.0cm × 1.0cm was found statistically superior to the treatments followed by 1.5cm × 1.5cm and 0.5cm × 1.0cm having the value 10.83, 10.04 and 9.25 respectively but statistically at par with 2.0cm × 2.0cm. And, treatments 1.5cm × 1.5cm and 2.0cm × 2.0cm were also found statistically at par.

The dry matter of plant material consists of all its constituents excluding water. Dry matter accumulations in the seedlings are the product of the translocation of nutrients from the cotyledons and the photosynthesis performed. For this reason, the cotyledons tend to lose dry weight during the seedling growth (Diaz- Ruiz *et al.,* 1999).

Table 3: Effect of seedling density in morphological character of Broccoli in Lamjung in 2018

Treatment (cm^2)	Plant height (cm)	Root length (cm)	Leaf area (cm^2)	No. of leaves	Root FW(g)	Shoot FW (g)	Shoot DW (g)	DW %
0.5 × 1.0	9.08^{a}	4.32^{b}	21.01^{c}	2.560	0.048^{b}	1.61	0.156	9.25^{c}
1.0 × 1.0	8.03^{b}	4.32^{b}	28.43^{b}	3.000	0.078^{a}	1.94	0.209	10.83^{a}
1.5 × 1.5	8.13^{b}	4.45^{b}	26.00^{b}	2.840	0.058^{ab}	1.80	0.180	10.04^{b}
2.0 × 2.0	7.71^{b}	5.20^{a}	40.36^{a}	3.080	0.084^{a}	2.34	0.244	10.65^{ab}
Grand mean	8.24	4.572	28.95	2.87	0.067	1.92	0.197	10.19
LSD (0.05)	0.898*	0.4830*	3.05**	NS	0.025*	NS	NS	0.740*
SEm±	0.291	0.1567	0.99	0.1242	0.008	0.247	0.024	0.240
CV%	7.9	7.7	7.6	9.7	27.5	28.7	27.4	5.3

*NS non-significant, * significant at 5% and **highly significant at 1%,*
Values within the same column with a common alphabet are not significantly different

IV. Conclusion and Recommendations

Seedlings in the spacing of 2.0cm×2.0cm performed better in respect of most of the studied morphological characteristics like: number of true leaves, leaf area and root length for production of quality seedlings in comparison with other closer spacing. And these parameters support better growth, development and establishment of the transferred seedlings. Since the trend shows better performance on decreasing the seedling density, we have to conduct further research in wider spacing to find out the optimum one before making any recommendation.

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