Influence of spacing and mulching on strawberry (*Fragaria* x *ananassa* Duch.) cv. Sweet Charlie in Assam

ABSTRACT

Plant spacing and mulching material have effects on crop growth and yield as they play a vital role in conserving soil moisture, enhancing nutrient and moisture uptake, regulating soil temperature and reducing weed growth. Evident research gap exists on effects of spacing and mulching on growth and development of strawberry. Strawberry is a surface feeder crop, and hence, mulching plays a very important role in providing optimum conditions for root development. Therefore, a field experiment was conducted at the farmer's field in Jorhat district of Assam, during 2019-20 and 2020-21 to study the effect of plant spacing and mulching on root volume of strawberry cv. Sweet Charlie. The experiment was laid out in a randomized block design with three replications based on 2 factors *viz*. plant spacing and mulch material. The trial consisted of a total of twenty treatments keeping five different plant spacing levels *viz*., 20 cm × 30 cm (S_1), 30 cm × 30 cm (S_2), 30 cm × 40 cm (S_3), 40 cm × 40 cm (S_4), 40 cm × 60 cm (S_5) and four different mulching materials viz., paddy straw (M_1), red mulch (M_2), silver black mulch (M_3) and no mulch (M_4). Results revealed that 40 cm × 60 cm spacing under silver black mulch recorded maximum root volume which may have a positive impact on crop yield.

Keywords: *Crop geometry, Mulch, Root volume, Spacing, Strawberry*

INTRODUCTION

Strawberry (*Fragaria* × *ananassa* Duch.) a prominent fruit crop, belonging to the Rosaceae family is cultivated worldwide (Jadhao and Dey, 2021). The total area of cultivated strawberry in

India during the year 2019 was reported to be 3.95 thousand hectares with global production of 9.2 million tonnes (Mahmood *et al.*, 2021). Enhancing strawberry yield in terms of both quantity and quality under limited land resource is the need of the hour (Meena *et al*., 2023). Crop growth as well as yield of strawberry can be enhanced by manipulation of crop geometry and crop management techniques. The space available to plants directly influences growth and development of particular plant. Optimum plant spacing helps in sufficient harvesting of solar radiation and adequate absorption of nutrients and moisture from the soil due to well-developed root system by making changes in inter and intra row spacing. Extensive root growth and expansion in all directions diminish competition between plant roots thus expanding water and nutrient uptake which will enhance the volume of plant roots (Hanum, 2018). The competition between neighboring roots may decrease soil nutrient resources thereby inhibiting root growth. Generally, in areas free of other roots, plants grow roots more preferentially (Gersani *et al*., 2001). Toxic exudates by plant roots may cause non-specific inhibitory effects on root of neighboring plants and also non-toxic chemical signals in genetically similar plants may specifically affect the roots of nearby plants (Jiang *et al*., 2013). Kashkool *et al*. (2020) in his study reported those wide distances between plants leads to maximum root growth. Mulching has impact on soil temperature, soil moisture regulation, boosts water and nutrient absorption, minimize weed growth and improves fruit quality by avoiding the direct contact of soil with fruit (Kijchavengkul *et al.*, 2008). Mulching has got advantageous condition for water and temperature which have an impact on the root system of the plant, encouraging root development and enhancing root secretion (Wang *et al.*, 2021). Mulch inhibit water runoff and helps soil with more time for absorption of rainwater and this supplementary moisture facilitates plant root expansion, that to a greater extent stabilizes the soil by promoting root growth (El-Beltagi *et al*., 2022). Mulches also build up congenial environment for root growth that encourages plant growth and productivity (Kader *et al*., 2019). According to Stephen *et al* (2019) white-striped mulch treatments resulted in increased growth, earliness, and yields of strawberry. This was due to reduced root-zone temperatures measured at the bed center under white-striped mulch throughout the hottest midday hours of November. The magnitude of improvement depended on cultivars and seasonal weather conditions.

Root volume appears to be a very significant index of plant growth as there is always competition between individual plants for nutrition, water and root space. Insufficient reports are available regarding root volume under different plant spacing and mulching in strawberry. In this study, root volume under different conditions of plant spacing and mulch were investigated to provide guidelines for optimizing crop geometry and suitable mulch material in strawberry production.

MATERIALS AND METHODS

The trial was done at the farmer's field at Jorhat district of Assam, India during two consecutive years 2019-2020 and 2020-2021. The field experiment plot was laid out in factorial randomized block design and consisted of three replications. The tissue culture strawberry plants of variety Sweet Charlie were planted in open condition in the experimental plot. There were 20 treatment combinations comprising of five plant spacings *viz*., 20 cm × 30 cm (S_1), 30 cm × 30 cm (S_2), 30 cm × 40 cm (S_3), 40 cm × 40 cm (S_4), 40 cm × 60 cm (S_5) and four different mulch applications *viz*., paddy straw (M_1), red mulch (M_2), silver black mulch (M_3) and no mulch (M_4). Root volume after harvesting of the crop was recorded. The root volume was measured by water displacement method as suggested by Mishra and Ahmed (1987) and expressed in cubic centimetre (cc). The plant roots were scooped and adhered soil removed carefully without damaging the roots. The volumes of the water in the cylinder were recorded before and after submerging the roots into the cylinder. Statistical analysis of pooled data was performed using windows-based computer software OPSTAT (Sheoran *et al*., 1998).

RESULTS AND DISCUSSION

The various treatments exerted influence on root volume of strawberry and the observations recorded as influenced by the treatments are presented in table 1. The combined analysis of both years data revealed that the maximum root volume (23.62 cc) was observed under plant spacing of 40 cm × 60 cm (S_5), followed by spacing of 40 cm × 40 cm (S_4) with root volume 22.80 cc while the minimum root volume of 19.65 cc was reported under 20 cm × 30 cm (S_1).

Table 1: Effect of spacing (s), mulching (m) and their interactions (s × m) on root volume (cc)

Treatment	Root volume (cc)		
	2019-2020	2020-21	Pooled
Spacing (s)			
S_1	20.42^{e}	18.88^{d}	19.65^{e}
S_2	21.66^{d}	19.84^{c}	20.75^{d}
S_3	22.46^{c}	21.04^{b}	21.75^{c}
S_4	23.22^{b}	22.37^{a}	22.80^{b}
S_5	24.20^{a}	23.04^{a}	23.62^{a}
SEd(±)	0.35	0.39	0.26
CD(P=0.05)	0.71	0.78	0.52
Mulches (m)			
M_1	18.07^{c}	16.54^{c}	17.30^{c}
M_2	26.44^{b}	24.67^{b}	25.55^{b}
M_3	31.24^{a}	29.98^{a}	30.61^{a}
M_4	13.82^{d}	12.95^{d}	13.38^{d}
SEd(±)	0.31	0.35	0.23
CD(P=0.05)	0.64	0.70	0.46

Interaction (s × m)

Treatment combination	2019-20	2020-21	Pooled	Treatment combination	2019-20	2020-21	Pooled
T1 (S1M1)	16.49	14.44	15.46	T11 (S3M3)	31.38	29.83	30.61
T2 (S1M2)	24.15	22.31	23.23	T12 (S3M4)	13.45	12.96	13.20
T3 (S1M3)	28.61	27.39	28.00	T13 (S4M1)	18.89	17.54	18.21
T4 (S1M4)	12.43	11.37	11.90	T14 (S4M2)	27.33	26.44	26.89
T5 (S2M1)	17.39	15.44	16.41	T15 (S4M3)	32.40	31.78	32.09
T6 (S2M2)	25.47	23.28	24.38	T16 (S4M4)	14.27	13.73	14.00
T7 (S2M3)	30.43	28.57	29.50	T17 (S5M1)	19.36	18.58	18.97
T8 (S2M4)	13.35	12.07	12.71	T18 (S5M2)	28.49	26.63	27.56
T9 (S3M1)	18.25	16.70	17.47	T19 (S5M3)	33.38	32.34	32.86
T10 (S3M2)	26.75	24.67	25.71	T20 (S5M4)	15.58	14.60	15.09

	2019-20	2020-2021	Pooled
SEd(±)	0.70	0.78	0.52
CD(P=0.05)	NS	NS	NS

[Superscript by same letter indicates they are at par; S_1: 20 cm × 30 cm; S_2: 30 cm × 30 cm; S_3: 30 cm × 40 cm; S_4: 40 cm × 40 cm; S_5: 40 cm × 60 cm; M_1: Paddy straw; M_2: Red mulch; M_3: Silver black mulch; M_4: No mulch; Plot size: 3 m^2; NS: Not significant]

Based on the pooled analysis of data the maximum root volume (30.61 cc) was observed in silver black mulch (M_3) and followed by Red mulch (M_2) with 25.55 cc; while minimum root volume (13.38 cc) was reported under no mulch condition (M_4). The interactions involving spacing and mulching exhibited non-significant effect on root volume during the two years of study period. The pooled data with treatment combination of spacing of 40 cm × 60 cm and silver black mulch (T_{19}) registered the maximum root volume (32.86 cc). Root volume is an important parameter that reflects the crop growth. Wider spacing reported considerably higher root volume which might have made air circulation in the soil and supplied oxygen for better root growth. This might help roots to come in contact with large volume of soil to absorb more nutrients and moisture for plant growth, resulting into higher dry matter production with higher nutrient uptake. The availability of sufficient space for individual plants improved the foraging capacity by the horizontal spread of roots that in turn, increased the root volume. Widely spaced plants produced higher root volume which could also be due to minimum competition for soil nutrients and solar energy that stimulated photosynthates accumulation in the roots. The results are in confirmation with the findings of Li *et al*. (2021), Misganaw and Yeshambel (2021) and Paramesh *et al*. (2013). Gao *et al*. (2023) in their study also found that at a closer plant spacing in cotton plants, the lateral roots exhibited densely overlapping growth and mainly competed for resources and when the competition for soil water between plants intensified, it resulted in reduction in total root volume.

The higher root volume under mulching might be primarily due to moderation of hydrothermal regimes leading to favorable soil-air-water relations, which encouraged proliferation and elongation of roots and the adequate moisture under mulches reduced the soil strength for root penetration and proliferation. Silver black plastic mulches are higher in reflecting Photosynthetically Active Radiation (PAR) than other mulches and also reduce water loss. The

lower root volume under no mulch treatment might be due to poor moisture levels in the soil and suboptimal thermal regimes. The results were supported by the findings of Wien (1993), Verma *et al.* (2005), Pandey *et al.* (2016), Kumar *et al.* (2018), Amare and Desta (2021), Kumar *et al.* (2021) and Rahmani *et al.* (2021). Chen *et al*. (2023) in their study also reported that with the increase of soil moisture, root morphological indexes such as total root volume increased. Liu *et al*. (2019) noted that when soil moisture was reduced, then root volume and other root growth indicators also decreased significantly. Ashrafuzzaman *et al.* (2011) reported that mulch produced higher root volume of Capsicum in comparison to the bare soil.

CONCLUSION

Strawberry is a surface feeder and shallow rooted crop that demands continuous maintenance of optimum soil moisture for better crop establishment, growth and yield. Soil moisture and nutrient stress influence the development of plant root system as the competition among plants for these resources will eventually affect the assimilation process by the competing root systems. Under wider plant spacing, there will always be minimum competition for space, light, air and nutrition among the plants and a favourable hydrothermal regime conditions will be provided by suitable mulching. Hence, it can be concluded that under ideal plant spacing and appropriate mulch material will have a positive impact on root volume of strawberry. The results indicated that 40 cm × 60 cm spacing with silver black mulch recorded maximum root volume in Strawberry. Root development and distribution are very significant for root-water and nutrient uptake studies in soil-plant systems. There is further scope of study on the response of different growing system on root architecture of strawberry. Moreover, a study on root characteristics of strawberry under various soilless growing systems can deepen the knowledge on strawberry cultivation under protected condition.

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

REFERENCES

Amare, G., Desta, B., 2021. Coloured plastic mulches: impact on soil properties and crop productivity. *Chemical and Biological Technologies in Agriculture* 8(4) DOI: https://doi.org/10.1186/s40538-020-00201-8.

Ashrafuzzaman, M., Abdul Halim, M., Ismail, M.R., Shahidullah, S.M., Hossain, M. A., 2011. Effect of plastic mulch on growth and yield of chilli (*Capsicum annuum* L.). *Brazilian Archives of Biology and Technology* 54(2), 321-330. 10.1590/S1516-89132011000200014.

Chen, X., Chen, Y., Zhang, W., Zhang, W., Wang, H., Zhou, Q., 2023. Response characteristics of root to moisture change at seedling stage of *Kengyilia hirsuta*. *Frontiers in Plant Science*, 13,1052791. https://doi.org/10.3389/fpls.2022.1052791.

Deschamps, S. S., Whitaker, V. M., & Agehara, S., 2019. White-striped plastic mulch reduces root-zone temperatures during establishment and increases early season yields of annual winter strawberry. *Scientia Horticulturae*. https://doi.org/10.1016/j.scienta.2018.09.018

El-Beltagi, H.S., Basit, A., Mohamed, H.I., Ali, I., Ullah, S., Kamel, E.A.R., Shalaby, T.A., Ramadan, K.M.A., Alkhateeb, A.A., Ghazzawy, H.S., 2022. Mulching as a sustainable water and soil saving practice in agriculture: a review. *Agronomy* 12(8),1881. DOI: https://doi.org/10.3390/agronomy12081881

Gao, C., Li, M., Li, D., 2023. Root architecture and visualization model of cotton group with different planting spacing under local irrigation. *Frontiers in Plant Science* 14,1080234. DOI: 10.3389/fpls.2023.1080234.

Gersani, M., Brown, J.S., O'Brien, E.E., Maina, G. M., Abramsky, Z., 2001. Tragedy of the commons as a result of root competition. *Journal of Ecology* 89,660-669. 10.1046/j.0022-0477.2001.00609.x.

Hanum, C., 2018. Growth, yield and movement of phosphate nutrients in soybean on P fertilizer, straw mulch and difference of plant spacing. In: *International Conference on Agriculture, Environment, and Food Security IOP Conf. Series: Earth and Environmental Science* 122,012051.

Jadhao,K.R., Dey, P., 2021. Phylogenetic Analysis of Strawberry, *Fragaria* × *ananassa* (Rosaceae: Fragaria) using Cytochrome C Heme Attachment Protein (ccsA) Gene. *Research Biotica* 3(3), 145- 153.

Jiang,W., Wang, K., Wu, Q., Dong, S., Liu, P., Zhang, J., 2013. Effects of narrow plant spacing on root distribution and physiological nitrogen use efficiency in summer maize. *The Crop Journal* 1, 77-83.

Kader, M.A., Singha, A., Begum, M.A., Jewel, A., Khan, F.H., Khan, N.I., 2019. Mulching as water-saving technique in dryland agriculture: review article. *Bulletin of the National. Research Centre 43*, 147. https://doi.org/10.1186/s42269-019-0186-7.

Kashkool, H.R., Radhi, N.J., Hassan W.F.,2020. Effect of plant spacing system and soil amendment in growth and yield of Rice plants (*Oryza sativa* L.) *Plant Archives* 20(1), 2710-2714.

Kijchavengkul T., Auras R., Rubino M., Gouajia M., Fernanadez, R.T., 2008. Assessment of aliphatic–aromatic copolyester biodegradable mulch films. Part I: Field study. *Chemosphere* 71(5), 942- 953.DOI: doi: 10.1016/j.chemosphere.2007.10.074.

Kumar, U.,2018. Performance of strawberry (*Fragaria* × *ananassa* Duch.) varieties under Western Malwa Plateau conditions. *M.Sc. (Hort) Thesis*,Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior.

Kumar, V., Chandolam, J.C., Prasad, S., Kumar, A., Patel, S.S., Regar, K.L., Singh, A.K., Kumar, M.,2021. Effect of mulching on weed biomass, root growth, yield and economics of tomato (*Lycopersicon esculentum* L.) in semi-arid region of Bihar. *Pharma Innovation Journal* 10(10), 1989-1991.

Li,Y., Yang,J.,Shi,Z.,Pan,W.,Liao,Y.,Li,T.,Qin,X.,2021. Response of root traits to plastic film mulch and its effects on yield. *Soil & Tillage Research* 209,104930.

Liu,T.Y., Chen, M. X., Zhang,Y., Zhu, F.Y., Liu,Y.G., Tian, Y., Fernie A.R., Ye, N., Zhang, J., 2019.Comparative metabolite profiling of two switchgrass ecotypes reveals differences in

drought stress responses and rhizosheath weight. *Planta* 250(4), 1355–1369. DOI: 10.1007/s00425-019-03228-w.

Mahmood, M.M., Al-Dulaimy, A.F.,2021. Response of strawberry cv. Festival to culture media and foliar application of nano and normal micronutrients. IOP Conf. Series: *Earth and Environmental Science* 904,1-11. DOI : 10.1088/1755-1315/904/1/012067.

Meena, R.L., Bunker, R.R., Ram, R.B., Meena, D.C., Meena, A.K., Meena, S.K. and Salvi A.,2023. The Efficacy of Different Mulching with Spacing on Growth and Yield of Strawberry (*Fragaria ananassa* Duch.) cv Chandler. *International Journal of Plant & Soil Science* 35(5), 59-68. DOI: 10.9734/IJPSS/2023/v35i52821

Misganaw, A., Yeshambel, Y., 2021. Effect of row spacing on growth and yield components of Carrot (*Dacusa carrot* L). *Journal of Horticulture* 8(2), 1-6.

Misra,R.D., Ahmed,M.,1987.Root parameters and their measurement. In: *Manual on irrigation agronomy.* Oxford and IBH Publishing Company Pvt. Ltd. New Delhi.pp:319-326.

Pandey, S., Tewari, G.S., Singh, J., Rajpurohit, D., Kumar, G.,2016. Efficacy of mulches on soil modifications, growth, production and quality of strawberry (*Fragaria* × *ananassa* Duch.). *International Journal of Science and Nature* 7(4), 813-820.

Paramesh, V., Sridhara, C.J., Shashidhar, K.S., 2013. Effect of integrated nutrient management and planting geometry on root parameter and nutrient uptake of aerobic rice. *Agriulture Update* 8(1&2), 217-220.

Rahmani, W., Salleh, M.N., Hamzah, M.Z., Abdu, A., Ishak, M.F., Khadir, W.R.W.A., Awang, M.R., Ibrahim, Z., Majid, A.F.A., Salleh, M.S.A., Anuar, A., Alias, M.A.B.,2021. Effect of different types of mulching on soil properties and tree growth of Magnolia champaca planted at the Montane Rainforest in Cameron Highlands, Pahang, Malaysia. *International Journal of Forestry Research* 2021, 1-11.DOI: https: // doi.org /10.1155 /2021/ 5517238

Sheoran, O.P., Tonk, D.S., Kaushik, L.S., Hasija, R.C., Pannu, R.S,1998. Statistical software package for agricultural research workers. In: *Recent Advances in information theory, Statistics*

& Computer Applications. (Eds.) Hooda, D.S. and Hasija, R.C. Department of Mathematics Statistics, CCS HAU, Hisar, pp. 139-143.

Tajima R., 2021.Importance of individual root traits to understand crop root system in agronomic and environmental contexts. *Breeding Science* 71(1), 13-19. DOI: 10.1270/jsbbs.20095.

Verma, M.L., Bhardwaj, S.P., Thakur, B.C., Bhandari, A.R.,2005. Nutritional and mulching studies in apple. Indian Journal of Horticulture 62(4), 332-335.

Wang, B., Wan, Y., Wang, J., Sun, J., Huai, G., Lv, C., Cui, L., 2021. Effect of biodegradable mulch film on maize yield and soil physical and chemical properties in Southern Xinjiang, China. *Hans Journal of Agricultural Sciences*, 11, 221-230. 10.12677/HJAS.2021.113033.

Wien, H.C., 1993. Polythene mulch stimulates really root growth and nutrient uptake of transplanted tomatoes. *Journal for the American Society for Horticultural Science* 118, 562-568.