Annals of Biology **40** (1) : 108-115, 2024

Impact Score : 0.32 (Scopus)

Productivity of Strawberry (*Fragaria x ananassa* Duch.) Genotypes under Open-field and Polyhouse Conditions in Subtropics of Punjab

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(Received: July 5, 2023; Accepted: August 9, 2023)

ABSTRACT

The climatic condition in India is highly suitable for commercial cultivation of strawberry under open field as well as polyhouse conditions. Further, the introduction of a wide range of strawberry genotypes has resulted in greater opportunities for its commercialization. However, it is important to evaluate the performance of existing and introduced genotypes under different growing conditions. The experiment was conducted to evaluate the performance of strawberry genotypes based on growth and yield potential of 10 strawberry cultivars (Winter Dawn, Camarosa, Dhankour, Nabila, Rania, Chandler, Sweet Charlie, Fern, Douglas and Selva) under open field and polyhouse condition. Though mortality was lower with early flowering and better plant growth attributes under polyhouse condition, the yield and fruit size were also reported to be superior in plants grown under polyhouse conditions. The highest fruit yield (g per plant) of strawberry under open field and polyhouse was recorded in cultivar Camarosa (387.147 and 468.887 g per plant, respectively) followed by Rania (355.423 and 377.907 g per plant, respectively) and Winter Dawn (302.493 and 374.340 g per plant, respectively). Among the various genotypes, Camarosa, Rania, Nabila, Dhankour and Winter Dawn have been reported to be suitable cultivars which can be adopted by the farmers for high yield and crop productivity under open field and polyhouse conditions.

Key words: Genotypes, mortality, plant spread, strawberry, yield

INTRODUCTION

Commercial cultivars of strawberry (*Fragaria x ananassa* Duch.) are octoploid (2n=8X=56) in nature and are the offspring of *Fragaria virginiana* and *Fragaria chiloensis*. As per the native, strawberry is suited to temperate climate; however, its cultivation has been commercialized in tropical and subtropical zones after evolution of new cultivars. Further, technological advancement like protected cultivation has enabled its commercialization under diverse climatic conditions. The cultivation of strawberry in India has been extended from Maharashtra to J. and K., including Punjab, Haryana, U. P., Delhi and Uttarakhand states. According to data related to Food and Agriculture Organization of the United Nations (FAOSTATs), China is the absolute leader in production of strawberry accounting for probably 3,336,690 tonnes during the year 2020 followed by USA with 1,055,963 tonnes of strawberry production (FAOSTAT, 2020). As per 2nd advance estimate of National Horticulture Database, the total area under strawberry cultivation in India is 1 lakh hectare with an annual production of about 8 million tonnes. India is also producing the export quality strawberry and contributing towards exporting strawberry fruits to countries like Austria, Bangladesh, Germany and Jordan.

The introduction of strawberry in India was done by NBPGR (National Bureau of Plant Genetic Resources), Regional Horticulture Research Station situated in Shimla and Regional Research Station, situated in Phagli of Shimla and Regional Horticultural Research Station, Shimla. The existence of broad genetic base is a challenge for breeder to evaluate and identify the suitable genotype for commercial cultivation and an opportunity for crop improvement program. Strawberry cultivation is equally suited to open field condition and protected cultivation. Singh and Kaur (2020) have evaluated five strawberry varieties under both open and protected condition and have reported Camarosa as the best cultivar for most of the plant growth and yield parameters with better vegetative growth of cultivars under open condition while the yield was better under protected condition. They have reported a wide

variation in plant height (19.08-22.11), plant spread (23.63-26.01 in N-S 22.92-25.31 cm E-W), number of runners per plant (3.98- 7.24), number of leaves per plant (32.01 to 44.06) and leaf area (104.35-108.32 cm^2) which could be associated with varietal variation due to difference in gene expression under prevailing climatic condition. The genes which were able to express vigorously were responsible for better plant growth, while the genotypes which poorly responded resulted in poor growth attributes. Panigrahi and Parihar (2020) evaluated 12 genotypes of strawberry under protected condition for various growth, flowering and fruiting attributes. They reported a significant varietal variation for plant height, plant spread, number of leaves and runners per plant which could be due to genes responsible for expression of various attributes at different level under existing agroclimatic condition. Anmol *et al.* (2021, 2022) evaluated strawberry genotypes for flowering, fruiting and yield attributes and reported 'Camarosa', 'Winter Dawn' and 'Chandler' with longest flowering period, good floral attributes, better fruiting and yield. Hence, a field experiment was conducted during 2020-21 and 2021-22 in the polyhouse and open field at Main Experiment Station of Horticulture, School of Agriculture, Lovely Professional University, Jalandhar, Punjab (India) to evaluate the performance of strawberry genotypes based on growth and yield potential of strawberry cultivars under open field and polyhouse condition.

MATERIALS AND METHODS

The experimental area was prepared well before planting by using spade. The experimental plot was prepared by making raised beds of 15 cm height and 45 m in length. The planting was done in double row system with bed to bed spacing of 40 cm, width of bed 80 cm, row - row spacing on each bed of 40 cm, while plant-plant spacing was kept as 30 cm. Seedlings were developed from runner of strawberry cv. Winter Dawn, Camarosa, Dhankour, Nabila, Rania, Chandler, Sweet Charlie, Fern, Douglas and Selva was used for planting. Fifteen kg of vermicompost was properly mixed well within soil to fulfil the recommended dose of fertilizer before planting the plants. Subsequently NPK 15-8-18 at the rate of 20-30 g/10 l of water was applied twice at 60 and 90 days after transplanting. The experiment was designed in randomized block design (RBD) under two different conditions over 10 strawberries of cultivars.

The observations were recorded on mortality (%) of seedlings, average plant height (cm), average plant spread (cm) in north-south and east-west direction, stem diameter, fruit size (diameter and length) and fruit yield per plant. The observations recorded on various parameters were statistically analyzed by using MS-Excel and R software. The recorded mean of all the parameters for each replication was exposed to statistical analysis for analysis of variance for randomized complete block design (RCBD). The genotypes were evaluated on 26 parameters and the recorded average replicated value of each quantitative trait was exposed to statistical analysis for estimation of correlation both at phenotypic and genotypic level (Illowsky, 2018), while the estimated value of correlation was tested for its significance by using t-statistics at n-2 error degree of freedom.

RESULTS AND DISCUSSION

The mortality (%) of fresh strawberry plants (Fig. 1) confirmed significant variation among different genotypes grown under open as well as polyhouse conditions. Under open as well as polyhouse conditions, the lowest mortality (%) in strawberry plant in year-1, year-2 and pooled data was estimated in cultivar Camarosa followed by Dhankour and Winter Dawn. The varieties which were found to be suitable for sub-mountainous and subtropical climatic condition of Punjab are Camarosa, Dhankour and Winter Dawn which might be associated with the adoptability of these genotypes in the existing climatic conditions and were also confirmed by the findings of Anmol *et al.* (2021, 2022).

It was also observed that mortality (%) was higher in the plants grown under open condition in comparison to plants grown under polyhouse which could be due to relatively controlled atmospheric conditions in polyhouse provided as suitable climatic conditions for survival of strawberry plants. Further, the disease prevalence in polyhouse condition was also lower which could be reason behind better survival of plants in this condition (Kumar *et al.*, 2021).

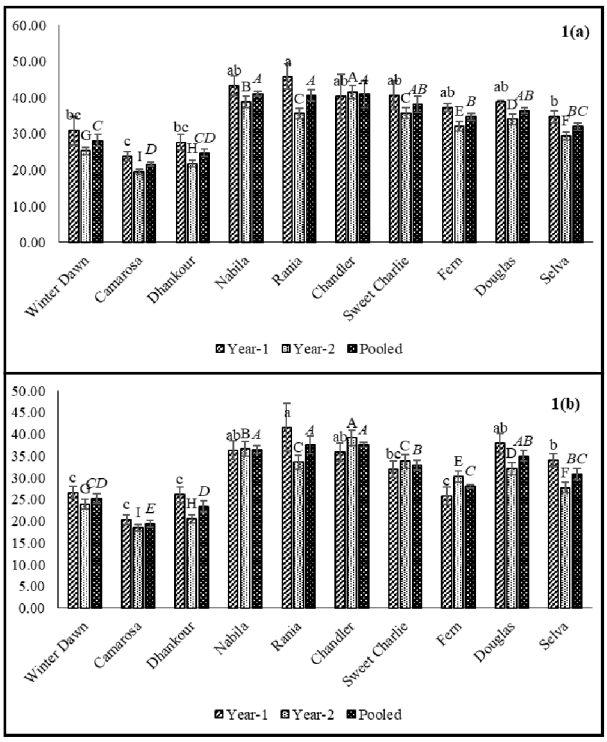

Fig. 1. Mortality (%) of strawberry plants grown under (a) open field and (b) polyhouse condition.

The plant height of strawberry plants (Table 1) confirmed significant variation among different genotypes grown under open field and polyhouse conditions. Under both growing conditions, the highest plant height at 65 days after transplanting in year-1, year-2 and pooled data was found in cultivar Rania which was at par to Nabila followed by Selva. However, in later phase of growth at 130 days after planting, the highest plant height in year-1, year-2 and pooled data was reported in cultivar Rania followed by Nabila and Camarosa. The observation confirms that Rania and Nabila have grown well at all phase of growth, while Camarosa and Chandler have shown better growth at later phase of life (at 130 days after planting). The present study confirms the suitability of genotypes Rania, Nabila, Camarosa and Chandler in the existing subtropical conditions of Punjab which could be attributed with their genetical make up and ability to express in the prevailing growing conditions. Quantitative reverse transcription-PCR as well as promoter analysis has confirmed the potential roles of *FvGRF* genes in the growth and development of vegetative organs in *Fragaria* (Li *et al.*, 2021).

The plant height was reported to be higher in the polyhouse condition in comparison to plants of open field (Table 1). The different growing conditions had variable influence on plants due to variability in available photoperiod, light,

Table 1. Average plant height (cm) of strawberry genotypes grown under open and polyhouse condition

Treatment	Open condition			Polyhouse condition		
	Year-1	Year-2	Pooled	Year-1	Year-2	Pooled
Average plant height at 65 days after planting						
Winter Dawn	7.680±0.160^{bc}	8.067±0.881^{a}	7.877±0.472^{bc}	8.123±0.173^{bc}	8.463±0.632^{a}	8.297±0.402^{bc}
Camarosa	7.477±0.238^{bc}	8.320±0.610^{a}	7.980±0.333^{bc}	7.813±0.229^{b}	8.483±0.542^{a}	8.150±0.379^{bc}
Dhankour	6.543±0.362^{c}	8.483±0.680^{a}	7.517±0.501^{bc}	6.713±0.271^{c}	8.833±0.717^{a}	7.773±0.331^{bc}
Nabila	8.723±0.346^{ab}	8.133±0.418^{a}	8.433±0.358^{ab}	8.767±0.328^{ab}	8.400±0.666^{a}	8.583±0.296^{b}
Rania	9.507±0.390^{a}	9.523±0.593^{a}	9.520±0.103^{a}	9.780±0.419^{a}	9.767±0.176^{a}	9.777±0.123^{a}
Chandler	7.237±0.208^{bc}	8.753±1.335^{a}	7.997±0.681^{bc}	7.467±0.208^{b}	8.733±0.536^{a}	8.100±0.171^{bc}
Sweet Charlie	6.933±0.521^{bc}	6.910±1.023^{a}	6.923±0.639^{c}	7.063±0.259^{c}	6.933±0.400^{a}	7.003±0.177^{c}
Fern	7.020±0.215^{bc}	7.783±0.526^{a}	7.323±0.290^{bc}	7.067±0.337^{c}	7.817±0.502^{a}	7.443±0.217^{c}
Douglas	7.417±0.723^{bc}	8.327±0.916^{a}	7.877±0.517^{bc}	7.567±0.771^{bc}	8.350±0.304^{a}	7.963±0.529^{bc}
Selva	7.773±0.098^{b}	8.293±0.319^{a}	8.037±0.165^{b}	8.400±0.259^{b}	8.533±0.623^{a}	8.470±0.421^{bc}
Average plant height at 130 days after planting						
Winter Dawn	10.283±0.224^{c}	9.653±0.077^{b}	9.970±0.090^{c}	11.710±0.074^{c}	10.583±0.159^{c}	11.147±0.084^{c}
Camarosa	11.590±0.690^{bc}	11.187±0.764^{b}	11.390±0.250^{b}	12.130±0.243^{b}	13.393±1.487^{b}	12.767±0.628^{b}
Dhankour	11.927±0.283^{b}	10.750±1.125^{bc}	11.340±0.420^{bc}	12.200±0.344^{b}	11.137±0.903^{c}	11.670±0.597^{c}
Nabila	12.320±1.004^{b}	11.543±0.452^{b}	11.937±0.277^{b}	13.023±0.261^{b}	12.233±0.812^{bc}	12.630±0.424^{b}
Rania	15.687±0.648^{a}	16.250±1.068^{a}	15.970±0.484^{a}	17.307±0.795^{a}	16.800±0.513^{a}	17.053±0.467^{a}
Chandler	10.037±0.481^{cd}	10.483±0.136^{bc}	10.263±0.256^{c}	11.263±0.098^{b}	13.310±1.488^{bc}	12.290±0.786^{b}
Sweet Charlie	8.573±0.466^{d}	9.037±0.114^{c}	8.807±0.237^{d}	8.733±0.079^{c}	10.433±0.233^{c}	9.587±0.079^{e}
Fern	8.683±0.222^{d}	9.130±0.481^{c}	8.907±0.292^{d}	9.743±0.549^{c}	11.367±0.720^{c}	10.173±0.378^{d}
Douglas	10.827±0.240^{bc}	10.010±0.481^{bc}	10.423±0.356^{c}	11.670±0.457^{b}	10.750±0.775^{c}	11.213±0.433^{b}
Selva	10.193±0.319^{cd}	10.527±0.650^{bc}	10.363±0.234^{c}	11.170±0.287^{b}	10.650±0.029^{c}	10.913±0.159^{b}

Superscripts are significantly same.

temperature and nutrient which could be a reason behind variation in growth attributes of strawberry cultivation (Gaikwad *et al.*, 2018). The plant spread of strawberry at 65 and 130 days after the transplanting confirmed significant variation among different genotypes grown under open field and polyhouse conditions. The highest plant spread (E-W) in year-1, year-2 and pooled data was observed in cultivar Rania followed by Nabila and Selva or Winter Dawn at 65 days after planting under both growing conditions, while at 130 days of transplanting, the plant spread (E-W) was highest in cultivar Rania followed by Camarosa and Nabila (Table 2). Thus, the observation confirms that the plant spread (E-W) was significantly higher in genotypes Rania, Camarosa, Nabila, Selva and Winter Dawn. The highest plant spread (N-S) (Table 3) in year-1, year-2 and pooled data was estimated in cultivar Rania followed by Selva, Nabila and Douglas at 65 days after planting under both growing conditions (Table 3). At 130 days after planting, the highest plant spread (N-S) was estimated in cultivar Rania followed by Camarosa, Winter Dawn and Nabila under open field as well as polyhouse conditions. It was observed that plant spread was higher in the polyhouse condition in comparison to plants of open field condition. Thus, overall plant spread of strawberry genotypes significantly varied with highest growth in Rania, Winter Dawn, Camarosa, Selva and Nabila which confirmed the suitability of these genotypes under prevailing climatic conditions. Kumar *et al.* (2021) also reported significant variation in genotypes for plant height, plant spread, number of runner formation and days to number formation which could be associated with the varietal difference in response towards the available grown condition. Further the variation in plant spread might be responsible for difference in photosynthetic activities and assimilation to ensure greater number of runner formation in these genotypes. Singh and Kaur (2020) advocated that the gene which was able to express vigorously be responsible for better plant growth, while the genotypes which responding poorly resulted in poor growth attributes.

The stem diameter of strawberry plant (Fig. 2) confirmed significant variation among different genotypes grown under open field as well as polyhouse conditions. The highest stem diameter was estimated in cultivar Rania followed by Douglas, Chandler and Selva. The observations confirmed that the stem diameter was significantly higher in most of

Table 2. Plant spread (E-W in cm) of strawberry genotypes grown under open and polyhouse condition

Treatment	Open condition			Polyhouse condition		
	Year-1	Year-2	Pooled	Year-1	Year-2	Pooled
Average plant spread (E-W) at 65 days after planting						
Winter Dawn	9.400±0.153^{bc}	10.717±0.985^{bc}	10.060±0.517^{bc}	11.663±0.665^{b}	13.033±0.338^{a}	12.350±0.489^{a}
Camarosa	9.400±0.115^{bc}	10.517±0.411^{bc}	9.960±0.155^{c}	10.957±0.387^{bc}	12.997±1.405^{a}	11.980±0.815^{a}
Dhankour	8.410±0.395^{c}	10.087±0.308^{c}	9.250±0.303^{c}	9.970±0.401^{c}	10.450±0.492^{a}	10.213±0.307^{a}
Nabila	10.797±0.333^{b}	10.370±0.415^{bc}	10.583±0.362^{bc}	13.177±0.668^{ab}	11.620±0.923^{a}	12.400±0.136^{a}
Rania	12.923±0.740^{a}	14.133±0.167^{a}	13.530±0.454^{a}	13.960±0.692^{a}	12.587±1.721^{a}	13.273±1.171^{a}
Chandler	9.213±0.199^{c}	10.783±0.650^{bc}	10.000±0.408^{c}	11.410±0.261^{bc}	11.933±2.791^{a}	11.673±1.499^{a}
Sweet Charlie	8.787±0.343^{c}	10.583±0.710^{bc}	9.690±0.516^{c}	9.473±0.628^{c}	10.767±1.027^{a}	10.123±0.401^{a}
Fern	9.067±0.577^{c}	11.060±0.643^{bc}	10.067±0.302^{bc}	10.007±0.455^{c}	10.450±0.477^{a}	10.230±0.452^{a}
Douglas	9.583±0.624^{bc}	11.107±0.861^{bc}	10.347±0.122^{bc}	10.937±0.332^{bc}	11.470±1.310^{a}	11.207±0.821^{a}
Selva	10.370±0.760^{bc}	11.633±0.498^{b}	11.003±0.534^{b}	11.810±0.357^{b}	12.033±1.472^{a}	11.923±0.854^{a}
Average plant spread (E-W) at 130 days after planting						
Winter Dawn	19.290±0.050^{b}	18.783±0.296^{c}	19.037±0.142	20.970±0.108^{b}	19.683±1.097^{c}	20.330±0.572^{c}
Camarosa	19.727±0.385^{b}	22.950±1.602^{ab}	21.340±0.921	20.680±0.598^{bc}	23.517±1.378^{b}	22.100±0.660^{b}
Dhankour	17.950±0.351^{cd}	21.267±1.631^{bc}	19.610±0.946	18.827±0.545^{c}	21.367±1.553^{bc}	20.100±0.755^{c}
Nabila	19.093±0.371^{bc}	21.350±1.843^{bc}	20.223±0.832^{b}	20.023±0.584^{bc}	22.383±0.928^{bc}	21.207±0.343^{bc}
Rania	23.093±0.455^{a}	25.900±1.575^{ab}	24.500±0.732^{a}	24.227±0.697^{a}	26.617±1.047^{a}	25.423±0.283^{a}
Chandler	17.297±0.333^{d}	22.533±2.679^{b}	19.917±1.502	18.147±0.522^{c}	23.593±1.644^{bc}	20.873±0.950^{bc}
Sweet Charlie	16.970±0.244^{d}	18.090±0.950^{c}	17.533±0.564	17.143±0.451^{c}	19.683±1.191^{c}	18.413±0.821^{d}
Fern	16.823±0.241^{d}	19.193±0.796^{bc}	18.010±0.520	17.013±0.447^{c}	19.633±2.067^{c}	18.327±1.217^{d}
Douglas	18.563±0.382^{c}	18.837±0.535^{bc}	18.703±0.357	19.490±1.167^{bc}	20.167±0.295^{c}	19.833±0.471^{cd}
Selva	19.587±0.705^{b}	18.627±0.989^{c}	19.110±0.829	20.140±1.279^{bc}	20.233±0.289^{c}	20.190±0.567^{c}

Superscripts are significantly same.

Table 3. Plant spread (N-S in cm) of strawberry genotypes grown under open and polyhouse condition

Treatment	Open condition			Polyhouse condition		
	Year-1	Year-2	Pooled	Year-1	Year-2	Pooled
Average plant spread (N-S) at 65 days after planting						
Winter Dawn	10.047±0.710^{c}	10.260±0.233^{c}	10.157±0.439^{cd}	11.823±0.517^{b}	12.973±0.279^{a}	12.400±0.368^{bc}
Camarosa	10.190±0.332^{c}	10.950±0.176^{bc}	10.573±0.084^{cd}	11.660±0.108^{bc}	12.287±1.206^{a}	11.977±0.552^{c}
Dhankour	9.467±0.191^{c}	9.767±0.219^{c}	9.617±0.160^{d}	10.133±0.264^{c}	11.780±0.696^{a}	10.960±0.474^{d}
Nabila	10.803±0.581^{bc}	11.583±0.505^{bc}	11.197±0.465^{b}	11.913±0.723^{b}	12.140±0.949^{a}	12.030±0.280^{c}
Rania	13.907±0.575^{a}	14.200±0.522^{a}	14.057±0.550^{a}	14.507±0.664^{a}	14.450±0.601^{a}	14.480±0.356^{a}
Chandler	10.433±0.706^{bc}	11.000±0.379^{bc}	10.720±0.391^{c}	11.807±0.585^{b}	13.600±1.253^{a}	12.707±0.637^{b}
Sweet Charlie	9.707±0.081^{c}	10.663±0.363^{bc}	10.187±0.200^{cd}	10.903±0.521^{bc}	13.063±1.342^{a}	11.983±0.438^{c}
Fern	9.243±0.217^{c}	10.937±0.845^{bc}	10.093±0.317^{cd}	10.007±0.143^{c}	13.650±1.226^{a}	11.830±0.561^{c}
Douglas	10.443±0.257^{bc}	12.033±1.017^{b}	11.240±0.382^{bc}	11.213±0.318^{bc}	12.500±1.353^{a}	11.860±0.525^{c}
Selva	11.680±0.469^{b}	12.567±0.698^{ab}	12.123±0.250^{b}	11.957±0.667^{b}	13.483±1.086^{a}	12.723±0.345^{b}
Average plant spread (N-S) at 130 days after planting						
Winter Dawn	16.160±0.139^{b}	12.567±0.744^{bc}	14.367±0.329^{bc}	17.050±0.025^{b}	17.763±0.747^{c}	17.410±0.387^{c}
Camarosa	16.197±0.135^{b}	13.120±0.842^{bc}	14.660±0.487^{bc}	16.693±0.290^{bc}	24.150±1.800^{ab}	19.007±1.363^{b}
Dhankour	14.753±0.127^{c}	11.583±0.725^{c}	13.170±0.307^{cd}	15.200±0.259^{c}	20.717±1.781^{bc}	17.067±1.278^{c}
Nabila	15.687±0.134^{bc}	14.303±0.369^{b}	15.000±0.171^{b}	16.160±0.280^{bc}	23.367±0.933^{b}	18.533±1.217^{b}
Rania	18.983±0.167^{a}	16.620±0.956^{a}	17.803±0.422^{a}	19.557±0.351^{a}	27.300±0.936^{a}	22.590±1.462^{a}
Chandler	14.223±0.124^{cd}	12.993±0.561^{bc}	13.613±0.342^{cd}	14.650±0.263^{c}	22.520±2.690^{bc}	16.880±1.559^{cd}
Sweet Charlie	12.553±0.443^{d}	11.210±0.353^{c}	11.883±0.287^{d}	12.843±0.433^{d}	18.463±1.421^{c}	14.117±0.644^{f}
Fern	13.000±0.110^{d}	11.583±0.738^{c}	12.293±0.332^{d}	13.980±0.637^{cd}	19.013±1.884^{c}	14.580±0.922^{f}
Douglas	14.347±1.201^{c}	12.000±1.037^{c}	13.177±0.084^{cd}	15.027±1.308^{c}	18.910±0.779^{c}	15.267±1.611^{ef}
Selva	13.553±0.158^{cd}	13.383±1.228^{bc}	13.470±0.680^{c}	14.070±0.405^{cd}	19.447±0.527^{c}	16.283±0.704^{d}

Superscripts are significantly same.

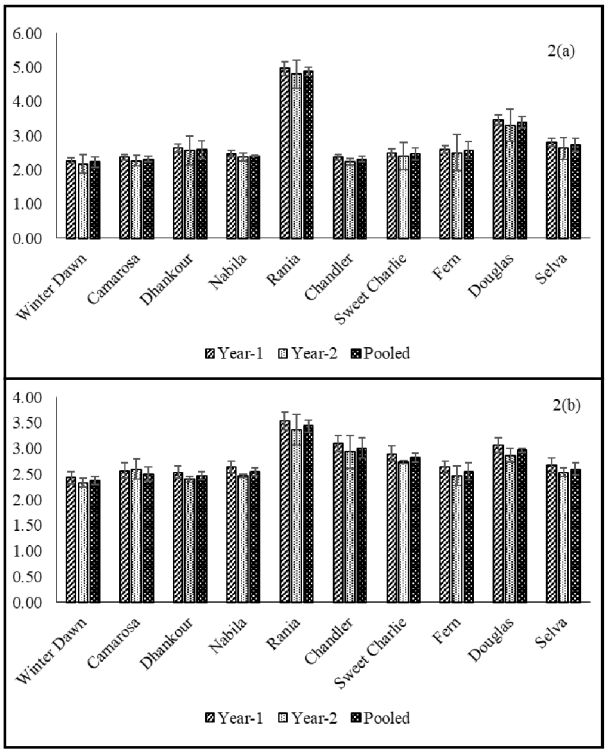

Fig. 2. Stem diameter of strawberry plants grown under (a) open field and (b) polyhouse condition.

the varieties in comparison to Camarosa, the commercially grown variety of strawberry in Punjab region. Further, the stem diameter was higher in the plants grown in open field condition in comparison to plants of polyhouse for most of the genotypes. This was associated with availability of sufficient solar radiation under open field condition resulting synthesis of photosynthates which are responsible for better growth of strawberry plants. Singh and Kaur (2020) advocated that the genes expressing vigorously were responsible for better plant growth attributes, while the genotypes which responded poorly resulted in poor growth attributes.

The observation on fruit diameter of strawberry (Table 4) confirmed significant variation among different genotypes and the highest fruit diameter under open field and polyhouse conditions was estimated in cultivars Rania, Nabila, Camarosa and Dhankour which were at par with each other. Under polyhouse, fruit diameter in Selva was also at par with these genotypes and was significantly high over others. However, the highest fruit length under open field and polyhouse conditions was estimated in cultivars Rania, Winter Dawn, Camarosa and Dhankour which were at par with each other (Table 4). Under polyhouse conditions, fruit length in Nabila was also at par with these genotypes and was significantly high over others. This reflected that the fruit size (length and diameter) was consistently

Table 4. Fruit size (mm) of strawberry genotypes grown under open and polyhouse condition

Treatment	Open condition			Polyhouse condition		
	Year-1	Year-2	Pooled	Year-1	Year-2	Pooled
Average fruit diameter						
Winter Dawn	28.043±0.293^{b}	25.810±0.013^{ab}	26.927±0.209^{a}	28.383±0.983^{b}	23.430±1.180^{a}	25.913±0.822^{ab}
Camarosa	29.243±1.351^{ab}	29.773±2.334^{a}	29.510±1.325^{a}	30.907±0.708^{ab}	23.007±0.397^{a}	26.960±0.542^{ab}
Dhankour	28.647±0.795^{b}	28.307±1.345^{ab}	28.480±0.974^{a}	30.883±0.555^{ab}	25.053±0.903^{a}	27.970±0.408^{a}
Nabila	30.043±0.912^{ab}	27.287±0.098^{ab}	28.670±0.495^{a}	28.843±1.121^{ab}	25.220±1.252^{a}	27.033±0.213^{ab}
Rania	31.310±0.960^{a}	27.280±3.291^{ab}	29.300±2.092^{a}	31.293±1.568^{a}	23.593±1.033^{a}	27.447±0.576^{a}
Chandler	24.877±0.509^{c}	22.003±1.547^{bc}	23.443±0.970^{b}	24.143±1.462^{c}	21.243±0.517^{a}	22.697±0.618^{c}
Sweet Charlie	22.227±0.739^{d}	19.653±1.015^{c}	20.943±0.678^{b}	20.577±0.877^{d}	20.953±0.332^{a}	21.070±0.351^{c}
Fern	26.893±1.033^{bc}	27.140±0.482^{ab}	27.020±0.755^{a}	26.190±0.283^{bc}	22.177±0.291^{a}	24.187±0.251^{bc}
Douglas	22.837±0.403^{c}	24.653±2.415^{b}	23.747±1.311^{b}	25.283±0.872^{c}	22.400±1.074^{a}	23.843±0.486^{bc}
Selva	24.280±0.297^{cd}	29.273±1.167^{ab}	26.780±0.704^{ab}	30.120±0.656^{a}	20.080±2.791^{a}	25.103±1.715^{b}
Average fruit length						
Winter Dawn	40.407±1.536^{b}	31.493±0.967^{c}	35.953±0.488^{bc}	33.093±1.231^{b}	28.787±0.792^{b}	30.943±1.013^{bc}
Camarosa	35.153±1.270^{c}	38.407±1.871^{b}	36.780±1.560^{b}	32.270±1.811^{b}	31.513±3.144^{b}	31.893±2.453^{b}
Dhankour	42.837±1.502^{a}	39.113±1.331^{b}	40.977±1.067^{a}	35.703±2.721^{ab}	37.753±3.138^{a}	36.730±2.249^{a}
Nabila	33.420±1.290^{d}	36.693±1.405^{bc}	35.060±1.248^{bc}	34.667±1.453^{ab}	36.207±2.315^{a}	35.437±1.504^{a}
Rania	35.233±1.624^{c}	46.067±0.150^{a}	40.650±0.835^{a}	38.210±0.639^{a}	37.240±0.575^{a}	37.727±0.592^{a}
Chandler	32.000±1.418^{ef}	35.267±2.543^{bc}	33.637±1.898^{c}	31.667±1.122^{bc}	29.507±0.637^{b}	30.590±0.858^{bc}
Sweet Charlie	26.273±0.902^{h}	29.613±1.670^{c}	27.947±0.489^{e}	21.550±0.768^{d}	20.630±0.693^{c}	21.090±0.727^{d}
Fern	31.360±1.120^{f}	32.820±0.401^{c}	32.093±0.533^{cd}	25.830±0.510^{c}	23.917±0.517^{c}	24.877±0.512^{c}
Douglas	32.203±1.328^{e}	29.520±2.477^{c}	30.863±1.168^{d}	28.147±1.120^{c}	27.300±1.731^{bc}	27.727±1.421^{c}
Selva	29.403±1.046^{g}	32.133±1.470^{c}	30.770±1.061^{d}	29.483±0.402^{bc}	28.967±0.618^{b}	29.227±0.404^{b}

Superscripts are significantly same.

high in cultivars Rania, Camarosa and Dhankour, while Nabila had greater fruit diameter and Winter Dawn had greater fruit length; however, Selva and Nabila performed differently and better under polyhouse condition.

The observation confirmed that Rania, Dhankour, Winter Dawn, Nabila and Selva had greater potential to perform under Punjab condition and were at par with Camarosa, the commercially grown variety of strawberry in Punjab region. Further, the fruit size was better in the fruits of open field condition in comparison to fruits of polyhouse. This could be attributed to the ability of these cultivars to adopt in the existing climatic conditions which confirmed the variation in productivity as a function of amplitude of plant response to the edapho-climatic where crop had grown (Zanin *et al.*, 2019) and to the ecophysiology of the crop (Chiomento *et al.*, 2021).

The average fruit yield per plant (g per plant) confirmed significant variation among different genotypes grown under open field as well as polyhouse conditions (Fig. 3). The highest fruit yield (g per plant) of strawberry under open field and polyhouse was recorded in cultivar Camarosa (387.147 and 468.887 g per plant, respectively) followed by Rania (355.423 and 377.907 g per plant, respectively)

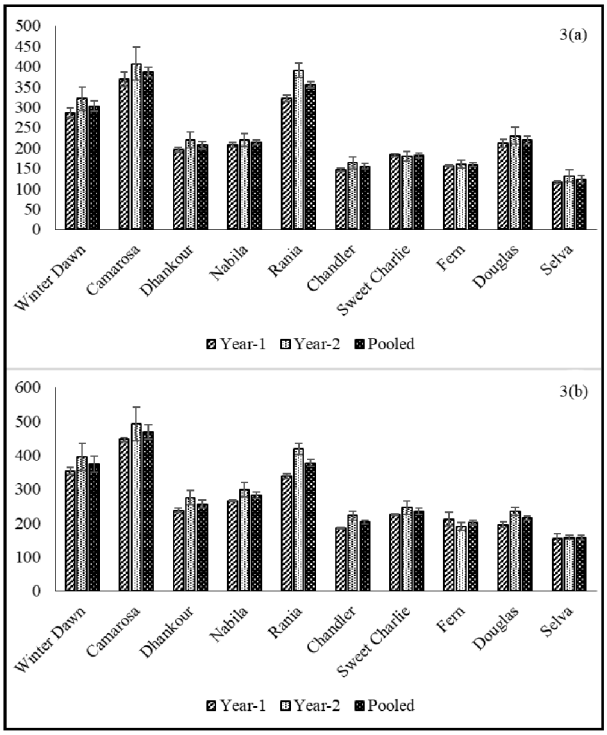

Fig. 3. Fruit yield of strawberry genotypes grown under (a) open field and (b) polyhouse condition.

Table 5. Correlation study between vegetative and yield attributes under open field (below the diagonal) and polyhouse (above the diagonal) conditions

Variables	Mortality	PH65 DAP	PH130 DAP	PS (E-W) 65 DAP	PS (E-W) 130 DAP	PS (N-S) 65 DAP	PS (N-S) 130 DAP	Stem diameter	Fruit diameter	Fruit length	Yield (g/plant)
Mortality	1	0.244^{ns}	0.269^{ns}	0.139^{ns}	0.159^{ns}	0.391*	0.091^{ns}	0.659**	-0.253^{ns}	-0.038^{ns}	-0.398*
PH65 DAP	0.255^{ns}	1	0.708**	0.460*	0.664**	0.451*	0.599**	0.354^{ns}	0.375*	0.601**	0.347^{ns}
PH130 DAP	0.136^{ns}	0.613**	1	0.536**	0.903**	0.697**	0.783**	0.548**	0.519**	0.750**	0.495**
PS (E-W) 65 DAP	0.386*	0.495**	0.730**	1	0.541**	0.498**	0.730**	0.342^{ns}	0.329^{ns}	0.408*	0.340^{ns}
PS (E-W) 130 DAP	0.067^{ns}	0.756**	0.826**	0.583**	1	0.704**	0.664**	0.390*	0.485**	0.705**	0.521**
PS (N-S) 65 DAP	0.459*	0.587**	0.699**	0.817**	0.546**	1	0.423*	0.521**	0.140^{ns}	0.322^{ns}	0.165^{ns}
PS (N-S) 130 DAP	0.147^{ns}	0.665**	0.853**	0.747**	0.763**	0.651**	1	0.475**	0.550**	0.649**	0.597**
Stem diameter	0.335^{ns}	0.459*	0.737**	0.799**	0.513**	0.764**	0.626**	1	-0.066^{ns}	0.114^{ns}	0.008^{ns}
Fruit diameter	-0.337^{ns}	0.382*	0.576**	0.303^{ns}	0.517**	0.212^{ns}	0.568**	0.211^{ns}	1	0.765**	0.497**
Fruit length	-0.271^{ns}	0.325^{ns}	0.701**	0.334^{ns}	0.575**	0.211^{ns}	0.618**	0.350^{ns}	0.719**	1	0.400*
Yield (g/plant)	-0.321^{ns}	0.365*	0.580**	0.358^{ns}	0.599**	0.265^{ns}	0.657**	0.335^{ns}	0.475**	0.587**	1

*, **Indicate significance at P=0.05 and 0.01, respectively. PH: Plant height, PS: Plant spread, N-S: North-south direction, E-W: East-west direction and DAP: days after planting.

and Winter Dawn (302.493 and 374.340 g per plant, respectively). The present study has confirmed significant variation in fruit yield among different strawberry genotypes under both, polyhouse and open field conditions. Among the various genotypes studied, Camarosa, Rania and Winter Dawn had performed well under both the growing conditions which confirmed the suitability of these genotypes for commercial cultivation under open as well as polyhouse conditions. The variation in yield response of these genotypes is result of their genetical make up which has been advocated by various authors. Kumar *et al.* (2020) had confirmed that the inherent potential of any genotype was another factor which determined the growth and yield of any cultivar. The genotypic response of cultivar can be altered by environmental condition as temperature can alter the photoperiodic response; however, the growth-related morphological attributes are regulated by a set of factors called growth regulating factors (GRF) which are the plant-specific transcription factors and are under control of GRF genes (Zhang *et al.*, 2018). These genes are also involved in regulation of cell expansion and proliferation to form different organs or flowering and fruiting. During regulation, a GRF-GIF transcriptional complex is formed due to association of GRF proteins and GRF-interacting factors (GIF; Kim, 2019) which promotes the regeneration in plant species (Luo and Palmgren, 2021). The present findings are in accordance to the work of Panigrahi and Parihar (2020).

The correlation study revealed that average yield of strawberry had significant and positive correlation with plant height at 65 days after planting (0.365*), plant height at 130 days after planting (0.580*), plant spread (E-W) at 130 days after planting (0.599**), plant spread (N-S) at 130 days after planting (0.657**), fruit diameter (0.475**) and fruit length (0.587**) under open field condition (Table 5). However, under polyhouse condition, there was significant and positive correlation with plant height at 130 days after planting (0.495**), plant spread (E-W) at 130 days after planting (0.521**), plant spread (N-S) at 130 days after planting (0.597**), fruit diameter (0.497**) and fruit length (0.400*), while mortality was negatively correlated (-0.398*) with yield. Barth *et al.* (2022) had also partitioned the correlation values for all genotypes of strawberry studied into phenotypic, genotypic and environmental contributions and had reported strong to moderate correlation between the various traits. The present study is in line with the findings of Diel *et al.* (2020) for different genotypes of strawberry.

CONCLUSION

In the present study, the genotypes Rania, Nabila, Dhankour and Winter Dawn were reported to be suitable cultivars which can be adopted by the farmers for high yield and crop productivity under open field and polyhouse conditions. Further, among different genotypes studied under open filed and polyhouse conditions, the mortality was lower with early flowering and better plant growth attributes under polyhouse condition in comparison to plants in open field. The fruit yield per plant (g) of strawberry was higher in the plants of

polyhouse condition in comparison to plants of open field condition.

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