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Original scientific article

GGE BIPLOT ANALYSIS FOR SEED PRODUCTION POTENTIAL OF EUROPEAN CARROT (*Daucus carota* L.) GENOTYPES IN PLAINS AND SUBMOUNTENOUS ZONES OF PUNJAB

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Carrot (*Daucus carota* L.) is grown worldwide in two different groups namely Asian and European. However the seed production of European cultivars is not possible in tropical and sub-tropical areas with less chilling period. The present study was planned to find the suitable areas in Punjab near foothills of Himalaya for seed production of European cultivars. Therefore fifteen carrot genotypes stecklings were transplanted in three dates of sowing i.e. first week of December, first week of January and first week of February at two locations of Punjab namely Ludhiana and Langroya. Seed yield traits like number of branches, number of seeds per plant, seed weight per plant, 100 seed weight and seed yield per hectare were recorded. Combined analysis of variance showed highly significant differences for GE (genotype×environment) interaction indicating the possibility of stable genotypes. Seed production was better in location Langroya and better than location Ludhiana. Most of the genotypes showed stable performance with regard to seed yield and yield parameters in first week of December and first week of January by GGE Biplot. Number of branches were significantly higher in genotype Pusa Meghali which was statistically at par with P-3, PCO-4. Similarly PCO-4 showed maximum number of seeds per plant and PCO-6 showed the highest seed weight per plant and 100 seed weight. Moreover, seed yield per hectare for genotypes PCO-4, PCO-6 was significantly higher than other genotypes. The study showed that European cultivars of carrot i.e. Pusa Meghali, PCO-4 and PCO-6 cultivars can produce seed in submontaneous zones of Punjab.
Keywords: Biplot, Carrot, European, Genotypes, chilling requirement, Submontaneous

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INTRODUCTION

Carrot (*Daucus carota* L.) is biennial herbaceous species belonging to Umbelliferae family cultivated for edible roots (MALEK *et al*., 2012). Carrot covers 88 thousand ha area with 1456 thousand MT production in India and (ANONYMOUS, 2019). The area under Punjab is 6.69 thousand ha with an annual production of 197 thousand MT (ANONYMOUS, 2019). Seed is produced in umbels as the inflorescence of carrot is compound umbel. Seeds of carrot have aromatic, stimulant and medicinal properties (TAVARES *et al*., 2008).

Two main types of carrot are: Tropical or Asiatic types and Temperate or European types. Asiatic types of carrot are annuals and require 10˚-15˚C temperature for root development and 15.5-21.1˚C for developing color. Very high or low temperature is not conducive for proper development of roots. The temperature above 30˚C can cause undesirable strong flavor and coarseness in the roots. European types of carrot are more sensitive to temperature and require 4.8-10˚C temperature during the development of roots and contain orange coloured carrots viz. Nantes, Danver and Imperator.

The seed production of Asiatic varieties of carrot is generally practised in Punjab, Haryana, U.P. and parts of Rajasthan & Gujarat. Whereas the seed production of temperate varieties is feasible only in Sproon valley, Kullu valley, Kalpa valley of Himachal Pardesh., Kashmir valley of J&K and selected locations of Northeast region specially Sikkim, Arunachal Pradesh in India as seed formation of European carrots takes place at 12.2˚C-21˚C and these areas fulfills the low temperature requirement for bolting and flowering. The mild summer and low rainfall of hills especially during flowering and seed setting stages are beneficial. Although, temperate varieties produce roots in cool season in plains of North India but its seed production is viable in hills during winter or after over wintering. The Asiatic/tropical varieties have temperature requirement below 15˚C that may result in formation of seed stalks which is suitable for seed production and commonly seen in December-January in plains of north India. The temperate/European types need chilling/vernalizaton of 4-5˚C temperature for 40-60 days duration for bolting depending upon the range of temperature. Therefore, their seed production is organized in hilly areas. In Punjab, November to February months are considered as low temperature periods where minimum temperature may reach 2-3˚C (Figure 1) that is suitable for bolting and seed production of Asiatic varieties of carrot. However some areas of Punjab are adjacent to lower foothills of Himachal Pradesh which have comparatively lower temperature than other parts of the states. The low temperature duration is also longer in these areas (Figure 1). High temperature at flowering in carrot also caused desiccation of tertiary umbels due to reduced availability of pollen supply for secondary umbels and reduced the seed setting resulting in lower seed yield. Therefore these potential areas should be studied for seed production of European carrot. Further different genotypes may behave differently in these environments for their seed setting ability.

To meet the low temperature requirement of European carrot varieties, the steckling need to be transplanted in different months of the year in multi-location. In this situation, a multi-location trial (MLT) can help to understand the performance of genotypes over diverse environments by studying the stability of the genotypes across environments (SCAPIM *et al*., 2000). Mostly the MLT data are rarely utilized to their full potential, though data are collected on many traits. In analyzing such data, mostly genotype evaluation is limited on genotype main effects (G), while genotype x environment interactions (GEI) are ignored as noise or confounding factor (YAN and TINKER, 2006). For evaluation of genotypes, both G and GE must be considered simultaneously (YAN and TINKER, 2006; SABAGHNIA *et al*., 2008). The G and GE (GGE) biplot removes the E and integrates the G with GE interaction effect of a G×E dataset (YAN *et al*., 2000). Effectively it detects the GE interaction pattern in the data and can identify 'which-won-where' besides identifying different mega-environments (YAN *et al*., 2007). Therefore keeping in view the above points, the present investigation was planned to find out the feasibility of seed production of European carrot varieties in different locations of Punjab.

MATERIALS AND METHODS

Experimental details

The experiment was laid out as Split Plot Design keeping the locations as main plot, dates of steckling transplanting as sub plot and fifteen diverse genotypes as sub-sub plot with three replications. The locations were (L_1) Research Farm (Director Seeds Punjab Agricultural University, Ludhiana (30º 54" North latitude and 75º 50" East longitude at an altitude of 247 meters above sea level) and (L_2) KVK Langroya, Shaheed Bhagat Singh Nagar (31º 07" North latitude and 76º 07" East longitude at an altitude of 283 meters above sea level) during 2018-19. Ludhiana falls under central plain zone (Agro Climatic – I zone) having semi-arid climate whereas KVK Langroya falls under undulating plain region (Agro Climatic – III zone) of Punjab. Soil textures of Ludhiana and KVK, Langroya were sandy and loamy soils respectively.

Table 1. Fifteen diverse genotypes used in the study

Genotypes	Source	Symbols used
P-3	PAU, Ludhiana	G1
P-4	PAU, Ludhiana	G2
P-5	PAU, Ludhiana	G3
P-16	PAU, Ludhiana	G4
P-18	PAU, Ludhiana	G5
P-23	PAU, Ludhiana	G6
P-28	PAU, Ludhiana	G7
P-29	PAU, Ludhiana	G8
P-41	PAU, Ludhiana	G9
PCO-4	PAU, Ludhiana	G10
PCO-6	PAU, Ludhiana	G11
Carrot Nantes	IARI, New Delhi	G12
Carrot Early Nantes	IARI, New Delhi	G13
Pusa Meghali	IARI, New Delhi	G14
Arka Suraj	IIHR, Bangalore	G15

The temperature difference in both the locations during the experiment is given in Figure 1. The stecklings were transplanted at the spacing of 45 × 30 cm (45 cm between ridges and 30 cm among plants). Three dates for steckling transplantation i.e. First week of December (E_1), First week of January (E_2) and First week of February (E_3). These dates were coded as E_1, E_2 and E_3 environments in both the locations. Fifteen genotypes (P-3, P-4, P-5, P-16, P-18, P-23, P-28, P-29, P-41, PCO-4, PCO-6, Carrot Nantes, Carrot Early Nantes, Pusa Meghali and Arka Suraj) were evaluated for their seed production potential (Table 1). Proper agronomic and plant protection measures were followed for raising the mother root production and seed production stage of the crop.

Seed yield and component traits

The data was recorded for number of branches, number of seeds per plant, seed weight per plant (g), 100 seed weight (g) and seed yield (kg/ha). Number of branches were recorded from ten randomly taken seed plants and counted at harvesting stage. All fully grown branches along with the small tertiary branches were taken into consideration. Moreover, seed weight per plant taken from randomly selected ten plants and weighed using weighing balance. Also, 100 seed weight (g) were measured by taking hundred seeds from the total seeds collected from umbels selected from each replication and weighed by using electronic balance. Furthermore, seed yield (kg/ha) was also estimated by diving the total seed weight per plot.

Statistical analysis

Analysis of variance (ANOVA) for both experiments was done by using computer based program CPCS 1 (STEEL *et al.*, 1997) GGE Biplot model was used to produce biplot graphs which display the variability of genotypes and G×E interactions. The statistical theory of GGE methodology had been explained in detail by YAN and KANG (2003). For environment centered matrix, the data were subjected to singular value decomposition (SVD) by estimating each element of the matrix using the following equation:

$$Yij - \mu - \beta j = \sum \lambda_l \xi_{il} \eta_{lj} + \varepsilon_{ij}$$

Yij is the measured mean yield of genotype i in environment j, μ is the grand mean, βj is the main effect of environment j, being the mean yield in environment j, λ_l is the SV of *l*th principal component (PC), the square of which is the sum of squares explained by PC*l*, ξil is the eigenvector of genotype i for PC *l*, ηlj is the eigenvector of environment j for PC *l* and εij is the residual associated with genotype i in environment j. We used the software GGE biplot ver. 6.3 (YAN, 2001) in the analysis. The MLT data was analyzed without scaling (‘Scaling 0’ option) to generate a tester centered (centering 2) GGE biplot, as suggested by YAN and TINKER (2006). ‘Which-won-where’ option was used to identify which genotype was the winner in a given set of environment and to identify mega-environments.

RESULTS AND DISCUSSION

Analysis of Variance

Analysis of Variance (ANOVA) for five traits is given in Table 2. It depicted the effect of locations, date of sowings and genotypes on number of branches, number of seeds per plant, seed weight per plant, 100 seed weight and seed yield per hectare. Table 2 indicates the mean values for locations (L_1 and L_2), dates of sowing (E_1, E_2 and E_3) and genotypes (G1-G15) along with the interactions between locations × dates of sowing, locations × genotypes and dates of sowing × genotypes and locations × dates of sowing × genotypes. ANOVA for seed yield and its components traits was presented in Table 3. The recorded sum of squares, mean sum of squares and F ratio depicted the significant variability among genotypes, locations and dates of sowing.

It also demonstrated the significant interactions between locations, genotypes and dates of sowing for seed yield and its contributing parameters.

Table 2. Descriptive statistics for seed yield and related traits

		Number of branches	No. of Seeds per plant	Seed weight per plant (g)	100 seed weight (g)	Seed yield per hectare (kg/ha)
Locations	L1	50.39	5629.12	11.96	0.16	349.88
	L2	47.43	5699.11	12.73	0.17	397.19
	CD (5%)	1.66	NS	0.27	0.0072	12.80
Date of sowings	D1	50.23	7545.71	14.13	0.18	478.38
	D2	65.34	6621.96	12.76	0.16	430.43
	D3	31.16	2824.68	10.15	0.16	211.80
	CD (5%)	2.03	448.24	0.33	0.0088	15.68
Genotypes	G1	55.42	5351.23	10.50	0.15	318.57
	G2	50.45	4930.59	10.73	0.17	337.39
	G3	42.77	4899.16	1121	0.16	318.57
	G4	49.07	5622.14	11.97	0.16	367.96
	G5	48.39	5248.17	12.00	0.17	348.61
	G6	47.10	5327.60	12.03	0.16	338.09
	G7	48.63	5821.41	12.37	0.16	390.19
	G8	47.27	5798.50	11.91	0.16	368.86
	G9	47.44	5340.95	11.80	0.17	355.91
	G10	55.09	6608.24	13.84	0.17	428.87
	G11	44.49	6578.43	14.35	0.18	450.40
	G12	43.14	6380.65	13.78	0.17	432.10
	G13	46.98	6071.54	13.55	0.16	403.87
	G14	55.48	5630.21	12.80	0.16	372.38
	G15	51.93	5352.90	12.37	0.18	371.27
	CD (5%)	2.04	684.48	0.87	0.0077	37.07
	Locations × Dates of sowing	2.87	633.91	0.47	0.012	NS
	Locations × Genotypes	2.88	NS	1.23	0.010	52.43
	Dates of sowing × Genotypes	3.53	1185.56	1.51	0.013	64.22
	Locations × Dates of sowing × Genotypes	5.00	1676.64	2.13	0.019	90.82

Number of branches were significantly higher at location 1 (Ludhiana) and among the different dates of sowing, first week of January revealed maximum branches. MENGISTU and YAMOAH (2010) reported that number of primary and secondary branches differ significantly at different dates of planting. Among the genotypes, G14 showed maximum number of branches which was statistically at par with G1. Although, MUHAMMAD and MUHAMMAD (2002) elaborated that large number of branches compete for space, nutrients, light and air between the plants. GRAY *et al.* (1983) stressed on reducing the lateral branches and developed majority of seeds from primary umbels bearing on the primary branch.

Number of seeds per plant was at par in both the locations. However stecklings transplanted in first week of December showed maximum number of seeds which was significantly higher than other sowing dates. Among the genotypes, G10, G11 and G12 showed significantly higher number of seeds per plant than other genotypes. The possible reason for increase in seed number with early transplanting of stecklings may be due to maximum time for vegetative growth before it enters the reproductive phase where all the assimilates have been used in the seed formation. The difference in seed number for genotypes might be due to their genetic effect (LINKE *et. al.,* 2019).

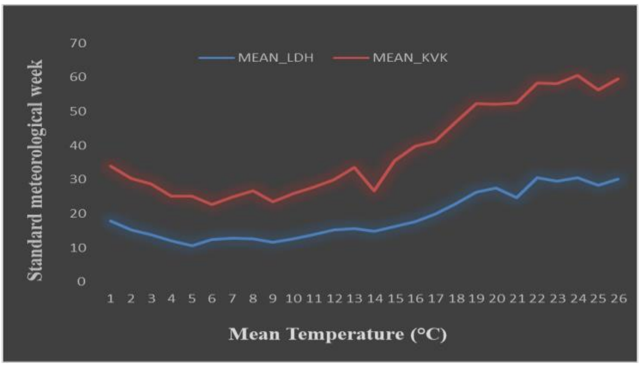
Seed weight per plant of G11, G10 and G12 genotypes were significantly higher as compared to other genotypes (Table 2). In comparison to locations, Seed weight per plant was maximum at Langroya when transplanted in first week of December. As location KVK, Langroya has comparatively less temperature than location Ludhiana (Figure 1) that might help in gaining more time for vegetative phase and this longer low temperature duration resulted in more flowering and thus resulted in more seed and seed weight per plant (GRAY *et al.* (1983). MENGISTU and YAMOAH (2010) reported that seed weight per umbel tend to decline progressively from November to February planting dates.

The genotypes G11 and G15 showed significantly highest 100 seed weight than other genotypes. 100 seed weight at location L_2 (KVK, Langroya) was significantly more (0.17) as compared to L_1 (Ludhiana). This may be due to smaller low temperature range in L_2 in comparison to L_1, in first week of December (first date of sowing). Seed weight depends on the time span between vegetative and reproductive phase, if the time period between vegetative to bolting phase is longer, it results in more number of branches and umbels per plant which will consequently enhance the seed weight per plant (GEORGE, 1985). Location L_2 (Figure 1) had comparatively lower temperature that fulfilled the requirement of temperate genotypes and resulted in more seed setting and increased seed weight per plant. KAHANGI *et al.* (1988) reported increase in one thousand seed weight ranged from 1 to 1.7 g in different seeds lots under different agro-climatic conditions of Kenya.

As far as seed yield per hectare is concerned, location Langroya (397.19 kg/ha) had significantly better than location Ludhiana (349.88 kg/ha). Furthermore, transplantation of stecklings in first week of December resulted in higher seed yield. As both these locations are sub-tropical, L_2 showed better results in terms of seed quantity of carrot. Seed yield had positive correlation with number of umbels, seed weight per plant and 100 seed weight (HAWTHORN and POLLARD, 1954; KRARUP and VILLANUEVA, 1977; JACOBSOHN and GLOBERSON, 1980; GRAY, 1981). Genotype 11 (PCO-6) showed highest seed yield per hectare followed by genotype 12 (Carrot Nantes) and genotype 10 (PCO-4). KAHANGI *et al*., (1988) recorded 3-9 t/ha of seed yield, superseding those reported under experimental conditions in temperate regions which normally did not exceed 2 t/ha.

Table 3. Analysis of variances (ANOVA) for seed yield and its contributing traits

Source	df	No. of Branches			No. of seeds per plant			Seed weight per plant (g)			100 seed weight (kg/ha)			Seed yield per hectare (kg/ha)		
		MS	SS	F ratio	MS	SS	F ratio	MS	SS	F ratio	MS	SS	F ratio	MS	SS	F ratio
Genotypes	14	306.19	4286.66	18.77	5349498.00	74892972.00	5.00	22.94	321.22	11.24	0.0010	0.0137	7.1000	29818.41	417457.74	9.50
Locations	1	590.29	590.29	674.51	325139.00	325139.00	0.22	71.69	71.69	38.00	0.0138	0.0138	247.6500	151041.20	151041.20	51.17
Dates of Sowing	2	26415.80	52831.60	32.13	0.56	1.13	294.64	393.50	787.00	290.31	0.0188	0.0377	21.4000	1817366.00	3634732.00	885.66
Locations x date of sowing	2	2917.72	5835.44	74.50	14879040.00	29758080.00	7.78	437.43	874.85	322.72	0.0035	0.0070	3.9700	2863.75	5727.50	1.40
Locations x genotypes	14	187.25	2621.50	19.65	1808794.00	25323116.00	1.69	8.15	114.04	3.99	0.0005	0.0065	3.3800	9607.53	134505.42	3.06
Date of sowing x genotypes	28	151.57	4243.96	15.90	2906897.00	81393116.00	2.72	10.66	298.42	5.22	0.0014	0.0397	10.2600	11913.28	333571.84	3.79
Locations x date of sowing x genotypes	28	124.70	3491.60	13.08	2480477.00	69453356.00	2.32	7.02	196.53	3.44	0.0006	0.0160	4.1400	8378.22	234590.16	2.67



*MEAN_LDH=Mean temperature at location L1 (Ludhiana)
*MEAN_KVK= Mean temperature at location L2 (KVK, Langroya)

Figure 1. Weekly meterological data recorded at meterological observatory during 2018-19 in Ludhiana (L1) and KVK, Langroya, SBS Nagar (L2)

Mean performance and stability of the genotypes

Performance and stability of genotypes were visualized graphically through GGE biplot in Fig 2 (a, b) – 6 (a, b). In the GGE-Biplot methodology, the first two principal components (PCA1 and PCA2), accounted for 49.74% and 43.25% of total variation, respectively, derived from the decomposition of singular values of the genotypes (G) + interaction effects (G×E). The first principal component (PCA1) indicates the adaptability of the genotypes, the second principal component (PC2) indicates stability, i.e., the genotypes closest to the biplot origin zero are the most stable (YAN *et al*., 2000).

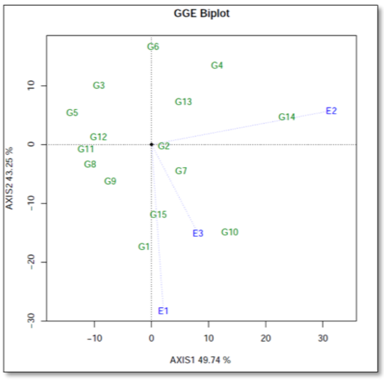


Fig 2 (a). GGE Biplot 1 for Number of branches of Carrot showing an interaction of 15 genotypes in 3 environments (E1-first week of December, E2-first week of January and E3-firstw eek of Febuary) at location L1 (Ludhiana)

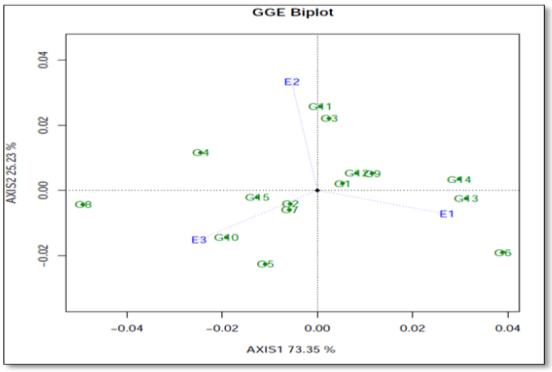


Fig 2 (b). GGE Biplot 1 for Number of branches of Carrot showing an interaction of 15 genotypes in 3 environments (three dates of sowing E1, E2 and E3) at location L2 (KVK, Langroya)

The visualization of GGE-Biplot "mean versus stability" for number of branches for location Ludhiana is presented in Figure 2 (a). This graph shows two lines, black dotted line is the average environment axis (AEA) or average environment coordination (AEC) abscissa, and the AEC ordinate. AEA is the line which is parallel to axis 49.74%, passing through the hypothetical average environment. The distance from AEA points to higher mean values for the measured trait; in this case, number of branches. However, G12 and G4 had the highest and lowest number of branches, respectively. The second black dotted line parallel to axis 43.25 % is the AEC ordinate which is also called stability line. This line passes through the origin and is perpendicular to the AEA. Average environment coordination (AEC) views of GGE-Biplot based on environment- focused scaling for means performance and stability of genotypes. AEC ordinate pointed higher instability (or greater variation) at both ends. Therefore, the shorter the projection or distance from AEA, the more stable or less variation in genotype performance among tested environments, and vice versa, i.e., G2 and G1 are the most stable and unstable genotypes for number of branches, respectively. This is in agreement with, yan and tinker (2006), who reported that "High stability" is desired only when it presents a high average performance. Despite the fact that genotypes G11 and G12 were considered stable, they had below-average number of branches and did not fit into ideal genotypes.

Figure 2 (b) illustrates the number of branches for location KVK, Langroya. It can observed that genotype G1 was the closest genotype to center of biplot and was highly stable at the L2. The best performing genotype in location 2 was G4 but expressed less stability. Although, genotype G15 expressed stability at location 2, it had below-average number of branches. In addition, G6 was the most unstable for the number of branches at L2.

Figure 3 (a) demonstrated the mean performance and stability of genotypes for number of seeds per plant trait under three environments i.e., E_1 (First week of December), E_2 (First week of January) and E_3 (First week of February) at L1 (Ludhiana). Above-average mean value for number of seeds per plant was scored for genotype G6 (observed closest to the center of the biplot), whereas below-average means were observed for G8 and G3. Therefore, genotype G14 proved to be the most unstable as it represents the longer distance from AEA for number of seeds per plant.

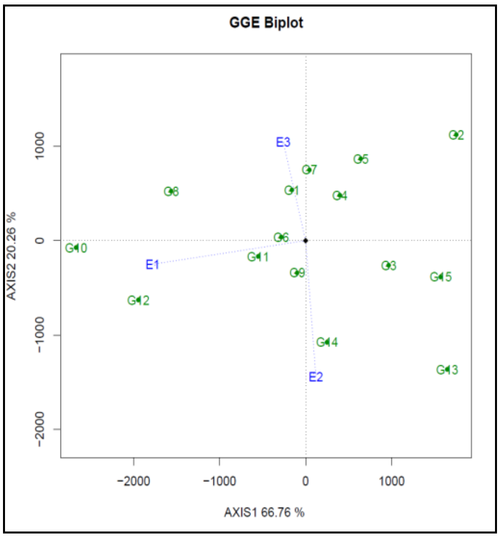


Fig 3 (a). GGE Biplot 1 for No. of seeds per plant of Carrot showing an interaction of 15 genotypes in 3 environments at location L1

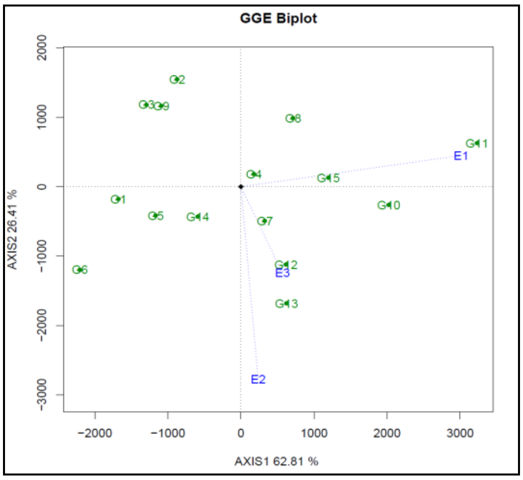


Fig 3 (b). GGE Biplot 1 for No. of seeds per plant of Carrot showing an interaction of 15 genotypes in 3 environments at location L2

The position of genotype 4 (P-16) in Figure 3 (b) was closest to the center of biplot with minimum distance from AEA and rewarded as the most stable genotype whereas genotype 14 expressed higher number of seeds per plant at L2 (KVK, Langroya). The genotype G13 showed the most unstable performance among the above genotypes. Instability of genotypes was predicted by the distance from AEA. The genotypes which were at the longest distance from AEA are unstable (TENA *et al*., 2019).

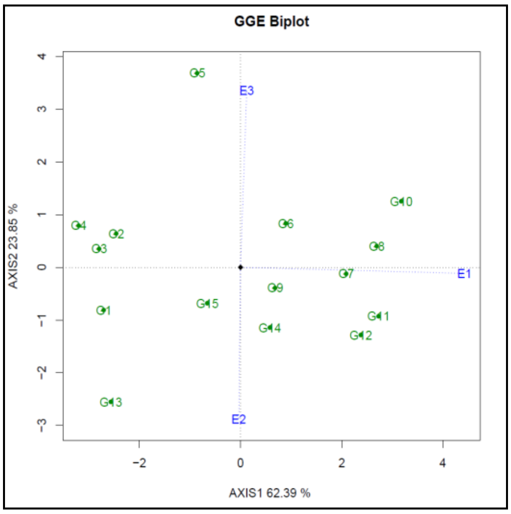


Fig 4 (a). GGE Biplot 1 for Seed weight per plant of Carrot showing an interaction of 15 genotypes in 3 environments at location L1

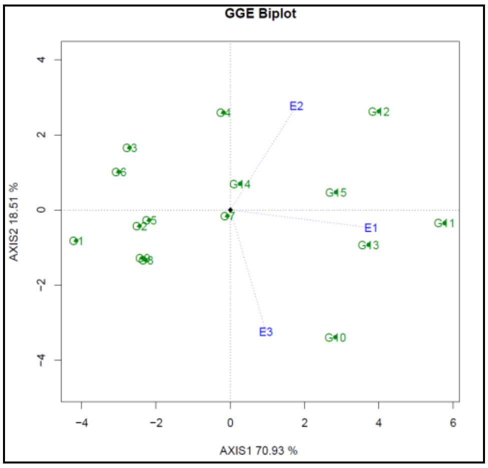


Fig 4 (b). GGE Biplot 1 for Seed weight per plant of Carrot showing an interaction of 15 genotypes in 3 environments at location L2

While examining Figure 4 (a) for seed weight per plant at L1 (Ludhiana) for three different environments E_1, E_2 and E_3, it was depicted that genotype G6 was the most stable as it stands close to AEA in positive direction even though its seed weight was smaller compared to G10. Genotypes with below-average means for seed weight were G14 and G5 and were not considered as ideal genotypes. Furthermore, at L2 (KVK, Langroya) as shown in figure 4 (b), genotype G7 pondered as the best performing genotype and was stable in the environment. However, G15 indicated above-average means compared to G7. Genotype 4 (P-16) was not considered as the perfect genotype as it showed below-average mean performance. PHUKE *et al.* (2017) explained that the genotypes which are shown at largest distance from AEA in positive direction are regarded as the below-average mean performance genotype and vice versa.

The partitioning of GGE through GGE-Biplot analysis showed that PC1 and PC2 accounted for 73.35% and 25.23% of GGE sum of squares respectively for 100 seed weight at location 1 (Ludhiana) (Figure 5 (a)). The GGE-Biplot revealed the best performing genotypes under different environments E_1, E_2 and E_3 and displayed the stability of genotypes i.e., G1, G12 and G9 are the most stable and best performing genotypes for 100 seed weight. However, compared to other genotypes, G14 had above-average mean value for 100 seed weight. The genotype G11 had below-average means and did not presented as the classic genotypes. The most unstable genotypes for 100 seed weight were genotype G8 and G6. Comparably, for second location (KVK, Langroya), the two main PC components represented 85.51% and 42.42% of GGE sum of squares respectively. Figure 5(b). Therefore, the best mean performance for 100 seed weight for location 2 was presented by genotype G7 which was also the most stable over the environment, while genotype G14 indicated the above-average mean. A study conducted by mortazavian et al. (2018) proclaimed that the genotype in positive direction with least distance from AEA had above-average mean and the most stable genotypes for cumin seeds compared in two different environments.

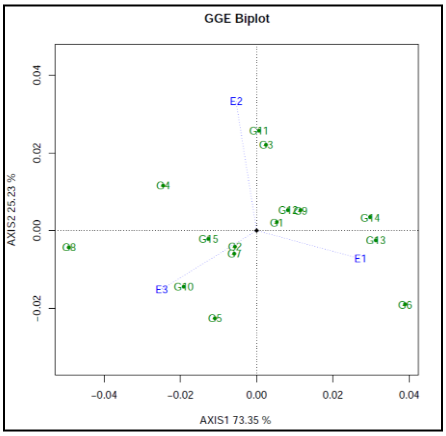


Fig 5 (a). GGE Biplot 1 for 100 Seed weight of Carrot showing an interaction of 15 genotypes in 3 environments at location L1

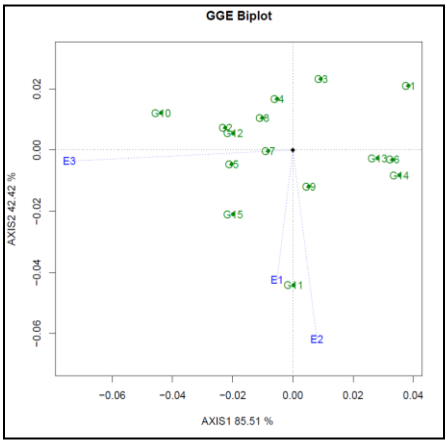


Fig 5 (b). GGE Biplot 1 for 100 Seed weight of Carrot showing an interaction of 15 genotypes in 3 environments at location L2

The best indicator of carrot commercial value is the seed yield per hectare. Mean performance and stability of genotypes for seed yield was given in Figure 6 (a). It was estimated that the genotypes G12 acquired the above-average means for seed yield for L1 but displayed least stability similar to description given in a study by RAMOS *et al*. (2017). Also, genotype G7 and G11 showed the average seed yield in the subsequent environment.

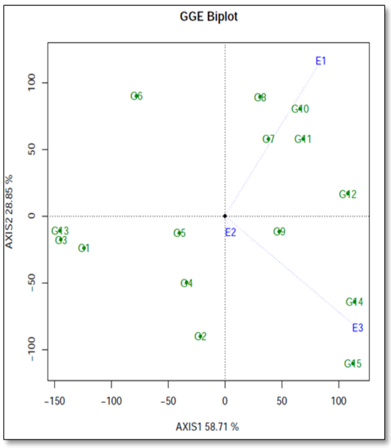


Fig 6 (a). GGE Biplot 1 for seed yield per hectare of Carrot showing an interaction of 15 genotypes in 3 environments at location L1 (Ludhiana)

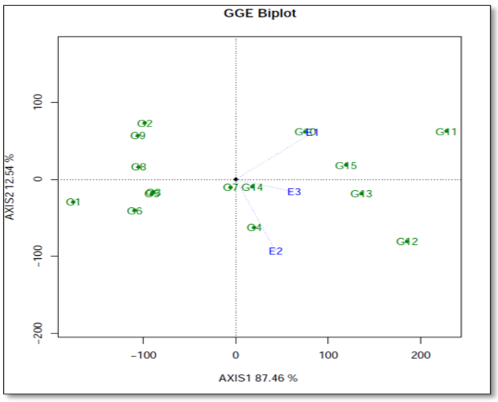


Fig 6 (b). GGE Biplot 1 for seed yield per hectare of Carrot showing an interaction of 15 genotypes in 3 environments at location L2 (KVK, Langroya)

Which-won-where Biplot

Which-won-where biplots for number of branches, number of seeds per plant, seed weight per plant, 100 seed weight and seed yield per hectare represented in Fig 2 (c-d) - 6 (c-d). Which-won-where graph illustrated the winning genotypes and presented it in the form of a polygon. The biplot polygon view illustrates which were the best performing genotypes in one or more environments (e.g., Fig 2 C). The genotypes that perform best were regarded as the wining genotypes. The lines originating from the center of the biplot and perpendicular to the sides of the polygon divide the plot into different sectors. Various sectors were developed by the lines that are perpendicular to the polygon sides and passing through the biplot center. These lines referred to as equality lines (YAN, 2001). Genotypes at the vertices of the polygon are either the best or poorest in one or more environments. The genotype at the vertex of the polygon performs best in the environment falling within the sectors (YAN and TINKER, 2006).

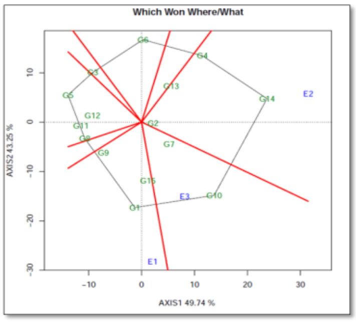


Fig. 2 (c). What Won Where GGE Biplot for Number of branches of Carrot showing an interaction of 15 genotypes in 3 environments at location L1 (Ludhiana)

Figure 2C demonstrated the winning genotypes for number of branches for three environments E_1 (First week of December), E_2 (First week of January) and E_3 (First week of February) at location Ludhiana. The genotypes G4 and G14 are winning genotypes for environment E2 and genotypes G1 and G10 are the winning genotypes with best performance in environment E3. Furthermore, figure 2 (d) provided the information that different genotypes won in different environments by performing their best performances at location KVK, Langroya for number of branches. The genotype G11 won in environment E_2 (First week of January), genotypes G14 and G6 performs best and won in environment E_1 (First week of December) whereas for environment E_3, the winning genotypes were G8 and G5.

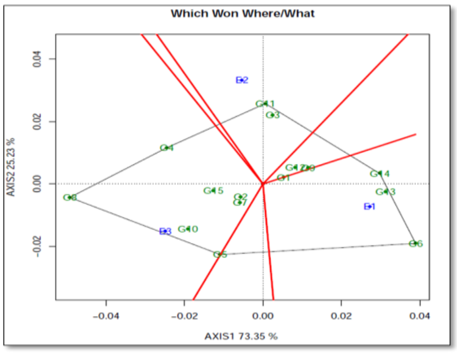


Fig. 2 (d). What Won Where GGE Biplot for Number of branches of Carrot showing an interaction of 15 genotypes in 3 environments at location L2 (KVK, Langroya)

Genotypes located on the vertices of the polygon performed best in either environment. The sectors developed by the equality line facilitate the visual comparison of genotypes among the tested environments. The winning genotype presented at the respective vertex of the biplot sectors suggested that G8 was the winner in the environment E_3 (Figure 3 C) for number of seeds per plant at location Ludhiana. Likewise, G10 and G12 were the winner genotypes for E_1 environment and also, for environment E_2, the best performing winner genotypes are G12 and G13. Moreover, Figure 3 (d) presented the winning genotypes G11 in environment E_1 and genotype G13 and G6 won in both environments E_2 as well as E3 for number of seeds per plant at location KVK, Langroya. It implied that the genotypes could win in target environment included different mega environments and thus different cultivars could be selected and deployed for each environment (YAN and TINKER, 2006).

For seed weight per plant polygon formed by genotypes at location Ludhiana presented in Figure 4 (c). The vertices of the polygon were formed by genotypes: G4, G5, G10 and G11, G13 and G12 and had highest vectors in their particular direction from biplot point of origin, were extreme genotypes and produced greatest contribution to G×E interaction. The other genotypes had smaller vector, which were contained within the polygon, means they were less sensitive to environmental interactions in each sector (YAN *et al*., 2007). Therefore, the best performing genotypes which won in the respective environment E_1 are G10, G11 and G12. The winner genotypes G12 and G13 were best performing in environment E_2 whereas genotypes G5 and G10 won in environment E_3 for seed weight per plant at location Ludhiana.

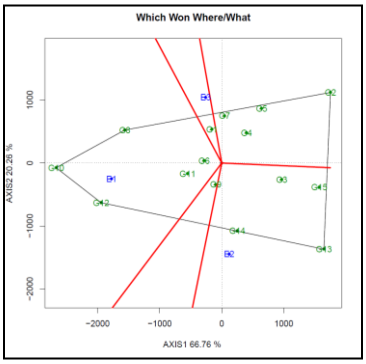


Fig 3 (c). Which Won Where GGE Biplot for No. of seeds per plant of Carrot showing an interaction of 15 genotypes in 3 environments at location L1

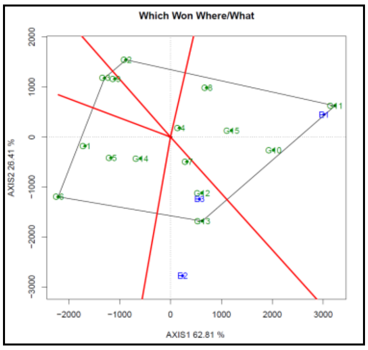


Fig 3 (d). Which Won Where GGE Biplot for No. of seeds per plant of Carrot showing an interaction of 15 genotypes in 3 environments at location L2

Figure 4 (d) depicted which-won-where biplot for location Langroya for seed weight per plant. In environment E_2, genotypes G4 and G12 had highest seed weight per plant and wins in subsequent environment. Likewise, genotype G11 and G10 wins in environment E1and winner genotype for environment E_3 is G10. Similar study was conducted by karimizadeh et al. (2013), in which they stated that when genotypes give rise to polygon vertices, they were considered favorable to groups of tested environments.

The winning genotypes in respective three environments E_1, E_2 and E_3 for 100 seed weight at location Ludhiana is presented in Figure 5 (c). Biplot presents the genotypes G8, G5, G6 and G14 and G11 connecting the polygon and had highest vectors and showed greatest contribution to G×E interaction. The best performing genotypes for E_1 are G14 and G6, winning genotypes

G5 and G8 for E_3 environment and G11 for environment E_2. Fig 5 (d) illustrated the winning genotypes G11 in environment E_1 and E_2, likewise, genotype G10 won in E_3 environment by performing the best for 100 seed weight at location KVK, Langroya.

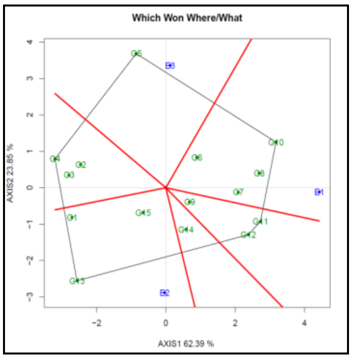


Fig 4 (c). Which Won Where GGE Biplot for Seed weight per plant of Carrot showing an interaction of 15 genotypes in 3 environments at location L1

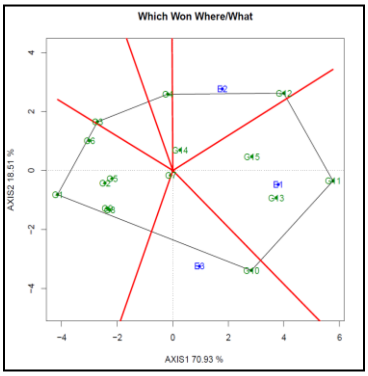


Fig 4 (d). Which Won Where GGE Biplot for Seed weight per plant of Carrot showing an interaction of 15 genotypes in 3 environments at location L2

The polygon view of the biplot indicated that G8 and G10 was specifically adapted to E_1 environment. Moreover, genotypes G14 and G15 with highest yield and best performance for seed yield won in environment E_3 at location Ludhiana (Fig 6C). Also, which-won-where biplot (Figure 6 (d)) for seed yield per hectare at location KVK, Langroya illustrated that genotype G10 and G11 won in environment E1and G4 and G12 are winner genotypes for environment E_2. These results suggested that G4, G10, G11 and G12 were particularly adapted to Langroya conditions in different environmental conditions. However, G10 performed best in E_1 at both locations and was best adaptive to Ludhiana as well as Langroya locations. The performance varied among the sowing dates at different locations, indicating the no repeatable G × E interactions BHARTIYA *et al. (2017)* and RAMOS *et al. (2017).*

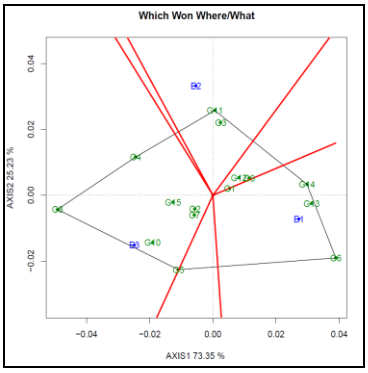


Fig 5 (c). Which Won Where GGE Biplot for 100 Seed weight of Carrot showing an interaction of 15 genotypes in 3 environments at locationL1

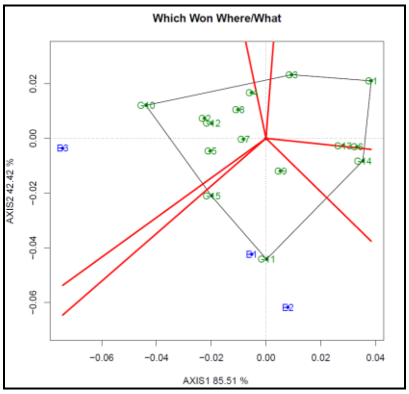


Fig 5 (d). Which Won Where GGE Biplot for 100 Seed weight of Carrot showing an interaction of 15 genotypes in 3 environments at location L2

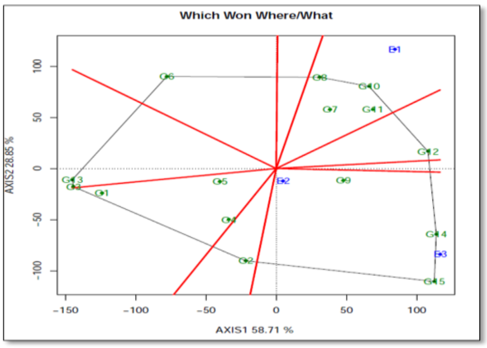


Fig 6 (c). Which Won Where GGE Biplot of seed yield per hectare of Carrot showing an interaction of 15 genotypes in 3 environments at location L1 (Ludhiana)

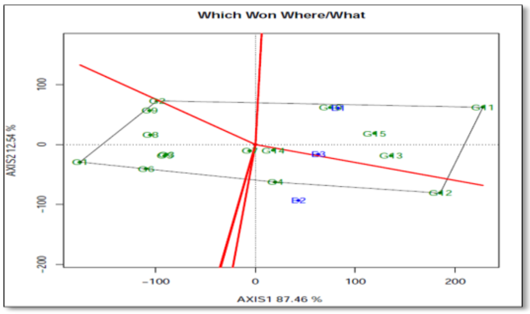


Fig 6 (d). Which Won Where GGE Biplot of seed yield per hectare of Carrot showing an interaction of 15 genotypes in 3

CONCLUSION

The results obtained from present investigation through ANOVA and GGE-Biplot conclude that European carrot genotypes performed well at both locations but results from KVK, Langroya was better. December and January transplanted stecklings performed better in seed yield and quality. Carrot Nantes, PCO-6, PCO-4, Pusa Meghali were the best genotypes for number of branches, seed weight per plant and seed yield per hectare. GGE Biplot predicts the stability of these genotypes in the particular environment and the stable genotypes can be grown in plains and submontaneous zones of Punjab.

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GGE BIPLOT ANALIZA ZA PROIZVODNI POTENCIJAL SEMENA GENOTIPA EVROPSKE ŠARGAREPE (*Daucus carota* L.) U RAVNICIMA I PODNOŽJIMA PLANINA U PODRUČJU PENDŽABA

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Izvod

Šargarepa (*Daucus carota* L.) se gaji širom sveta u dve različite grupe, azijskoj i evropskoj. Međutim, proizvodnja semena evropskih sorti nije moguća u tropskim i suptropskim oblastima sa kraćim hladnijim periodom. Ova studija je planirana da pronađe pogodna područja u Pendžabu u blizini podnožja Himalaja za proizvodnju semena evropskih sorti. Zbog toga je petnaest genotipova šargarepe rasađeno u tri datuma setve, odnosno prve nedelje decembra, prve nedelje januara i prve nedelje februara na dve lokacije u Pendžabu, Ludhiana i Langroia. Beležene su osobine prinosa semena kao što su broj grana, broj semena po biljci, masa semena po biljci, masa 100 semena i prinos semena po hektaru. Kombinovana analiza varijanse pokazala je visoko značajne razlike za interakciju GE (genotip×sredina) što ukazuje na postojanje stabilnih genotipova. Proizvodnja semena je bila bolja na lokaciji Langroia u odnosu na lokaciju Ludhiana. Većina genotipova je pokazala stabilne performanse u pogledu prinosa semena i parametara prinosa u prvoj nedelji decembra i prvoj nedelji januara prema GGE Biplot. Broj grana je bio značajno veći kod genotipa Pusa Meghali koji je statistički bio u rangu sa P-3, PCO-4. Slično, PCO-4 je pokazao maksimalan broj semena po biljci, a PCO-6 je pokazao najveću težinu semena po biljci i težinu od 100 semena. Štaviše, prinos semena po hektaru za genotipove PCO-4, PCO-6 bio je značajno veći od ostalih genotipova. Studija je pokazala da evropske sorte šargarepe, odnosno sorte Pusa Meghali, PCO-4 i PCO-6 mogu da daju seme u subplaninskim zonama Pendžaba.

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