Genetic characterization and variability analysis of Chickpea (*Cicer arietinum*) elite germplasm under different cropping conditions.

Abstract

In current study 113 diverse genotypes of chickpea has been evaluated during rabi 2019-20 and 2020-21 under timely sown (TS), late sown (LS) and very late sown (VLS) cropping environment in augmented block design at research farm of ICAR-IIPR, Kanpur for genetic characterization to access the presence of variability among the major grain yield attributing traits under changing cropping conditions. Variation due to block were insignificant and error variance was significant for all three different trials (ie., TS, LS and VLS) conducted during rabi 2019-20 and 2020-21(Table no. 5) In the present study highest genotypic and phenotypic coefficient of variation was observed for UFP, SYP (g), PB, Y (kg/ha), PY (g), HI (%), BMP (g), HSW (g) and FP (Table no.5) While the traits viz., DFI, DFF, DPI, DFP, DMI, DM and PHT (cm), BY (g) and NSP exhibited the moderate to low range of GVC and PCV value under TS, LS and VLS cropping conditions During rabi 2019-20 and 2020-21. Highest value of heritability (%) >60% have been observe for the traits DFI, DFF, DMI, DM, PB, Y (kg/ha), HSW (g), SYP (g), BMP (g) and FP in all three different cropping environments (Table no. In the current study correlation coefficient analysis have been estimated for the Correlation values (Table 6) for all three different trials viz Timely sown (TS), Late sown (LS) and Very Late sown (VLS) conducted in Rabi 2019-20 and 2020-2021. The Pearson correlation coefficients of pooled data were calculated for Eighteen morphological traits The major yield contributing traits such as DFF, PHT (cm), PB, SYP (g), PY (g), Y (g), HSW (g), BY (g) and HI (%) have significantly correlated with all the traits except UFP and NSP (Table no. 6) The PY (g) exhibited strong positive correlation with Y (Kg/ha) (0.857** and 0.964**); HSW (g) (0.544* and 0.412*); BY (g) (517* and 0.856**); SYP (g) (0.628**and 0.506*); BMP (g) (0.553* and 0.494*); HI (%) (0.459* and 0.706**). Similarly, another chief yield contributing traits like SPY (g) is also positively correlated BMP (g) (0.536* and 0.682**); HI (%) (0.678** and 0.779**); FP (0.774** and 0.964**) and NSP (0.456* and 0.503*) except UFP (Table no. Maximum percentage of variance for all 113 diverse chickpea genotypes has been recorded for PC1(26.83, 26.63 & 31.46 in 2019-20; 29.87, 35.15 & 30.2 in 2020-21) and PC2 (24.19, 22.81 & 12.66 in 2019-20; 18.96, 15.43 & 17.4 in 2020-21) for all three separate trials i.e., TS, LS and VLS (Table no. 7)

Key words:*Chickpea, Genetic characterization, variability, Correlation, PCA*

Introduction:

Chickpea (Cicer arietinum L.) is a cool season legume and ranks second among food grain legumes in the world after common bean. High temperature during the reproductive period can limit grain yield. High temperature (>30 ◦C) regulates floral initiation and grain yield in chickpea (Summerfield et al., 1984). At present, chickpea is generally produced in warm environments (Devasirvatham et al., 2012a) in rotation with cereals in northern and central region of India where sudden rise in temperature at pre-reproductive stage and during grain filling stage causes serious losses in yield. Heat stresses immediately after flowering affects the germination and pollen tube growth in chickpea (Devasirvatham et al. 2012b). The failure of fertilization in chickpea by heat stress is due to reduced stigma receptivity (Kaushalet al. 2013; Kumar et al. 2013). The ovule and ovary abnormalities affect the seed and pod set (Devasirvathamet al. 2013) leading to a reduction in seed weight and seed number. At peak flowering and pod filling stage, exposure to higher temperature ($>35_{0}$C) results in significant yield loss due to reduced seed size and seed number (Summerfield et al. 1984; Wang et al. 2006). With increase in 1°C seasonal temperature a minimum decrease of 53 kg of chickpea yield was observed in India per (Karla et al. 2008). predominantly, unexpected increase in temperature outside the standard accelerates the phenology of the crop, such as the days to blooming, days to pod fill and maturity days, leading to poor biomass development and eventually increases the number of empty pods which results and low seed yield (Bhandari et al., 2020). Seed yield under heat stress condition mostly depends upon the plant biomass, filled pods/ plant and seed yield/ plant (g) (Krishnamurthy et al. (2011)

In view of the foresaid fact is it serious need to develop heat stress resilient chickpea genotypes for sustainable chickpea cultivation and stable yield performance under high temperature stress condition during pre and post reproductive stages. Current study was aimed for the phenotypic and genetic screening of chickpea germplasm in 113 diverse germplasm which were evaluated under timely sown, late sown and very late sown environmental condition for two consecutive years to screen the variability and heat tolerant genotypes to utilise as a potential donor in further chickpea breeding programme to develop the heat tolerance variety.

Materials and methodology:

Present experiment was carried out at main research farm at ICAR-Indian Institute of Pulses Research, Kanpur (26^{o}29' N, 80^{o}16'E and 130m) Uttar Pradesh, India. All the 113 genotypes, comprising of released varieties, local landraces and ABLwere planted in ‘Augmented’ design in 5 blocks along with 5 checks viz., DCP 92.3, ICC 1205, ICC7110, ICC15614 and JG 14, all replicated in 5 blocks. The meteorological data Viz., Weekly mean of max temp., min temp, rain fall (mm), relative humidity and sunshine hours during crop growth stages (picture. 1) have been recorded. The seeds of each genotype were sown in 4m row length and row to row space was 30 cm apart both under Timely sown (TS), Late sown (LS) and very late sown (VLS) conditions in the year 2019-20 and in the year 2020-21(Table 1). Recommended doses of fertilizer (20N + 40P_2O_5kg/ha) were applied as basal dose. All other recommended crop management agronomic practices were followed to raise a healthy crop. Data on various phenological traits viz., Days to initial flowering (DFI), Days to 50% flowering (DFF), Days to pod initiation (DPI), Days to 50% podding (DFP), Days to initial maturity (DMI), Days to maturity (DM), Plant Height (PHT), Primary Branches/Plant (PB) and Nine traits linked with yield and yield attributes i.e., Biological Yield /Plant [BY (g)], Seed Yield/Plant [SYPP(g)], Plot Yield [PY(g)], Biomass/Plant [BMPP (g)], Filled Pod/Plant (FPP), Unfilled Pods/Plant (UFP), Hundred Seed Weight [HSW(g)], Harvest Index [HI (%)] and Seeds/Pod (SPP) have been recorded on five randomly selected plants and were subjected to various statistical analysis.

Analysis of variance, descriptive statistical analysis and genetic parameter estimates of augmented data have been computed for all three environments i.e., TS, LS and VLS conducted during rabi 2019-20 and rabi 2020-21by using Agricole package of “R” Studio software. The phenotypic correlation coefficients were computed in R software using methodology suggested by Pearson (1895).

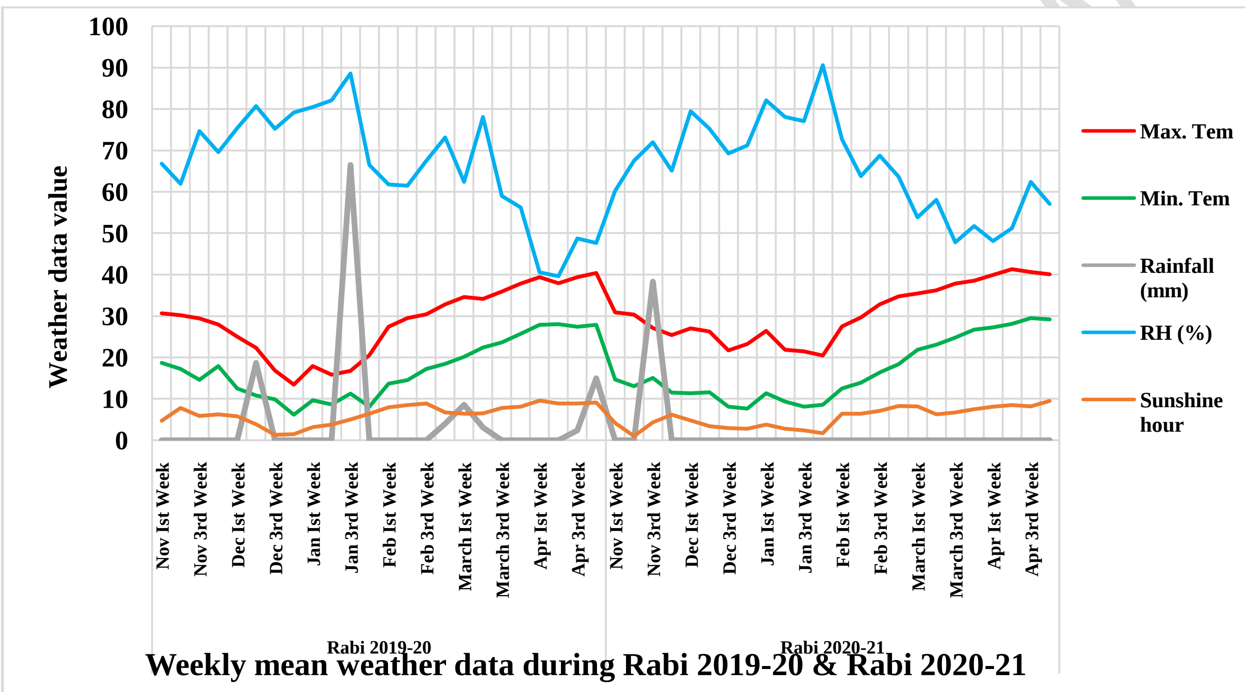
Table 1. List of entries used in the sudy

SL	Genotype	Originating centre	Parentage	Year	Area of adoption
1	BDG 72	IARI, New Delhi	(BG256/E100YM)/BG 256	1999	UP, MP, Gujrsat, Maharashtra, Rajasthan
2	**DCP 92-3 (CH)**	**IIPR, Kanpur**	Selection from local	**1998**	**NWPZ under irrigated**

			Germplasm		**condition**
3	GCP 105	GAU, Junagadh	ICCL 84224/Annegeri 1	2000	NEPZ
4	GG 2	GAU, Junagadh	JG 1258/BDN9-3	1999	Gujrat
5	GNG 663	Sriganganagar	GNG 16/GNG 146	1994	NWPZ (Rainfed)
6	GNG 1958	Sriganganagar	GNG 365/SAKI9516	2013	NWPZ (Irrigated)
7	**ICC 1205 (CH)**	ICRISAT, Hyderabad	Traditional cultivar / landrace collected from UP	1973	-
8	ICC 4958	ICRISAT, Hyderabad	Advanced improved line (JGC1) collected from MP	1973	-
9	**ICC 7110 (CH)**	ICRISAT, Hyderabad	Traditional cultivar / landrace collected from Lebanon	1974	-
10	**ICC 15614 (CH)**	ICRISAT, Hyderabad	Traditional cultivar / landrace collected from Tanzania	1989	-
11	IPC 12-31	IIPR, Kanpur	Katila/ICCV10	-	ABL developed by IIPR
12	IPC 12-211	IIPR, Kanpur	Katila/ICCV 10	-	ABLdeveloped by IIPR
13	IPC 14-56	IIPR, Kanpur	JG2001-4-1/KWR 108	-	ABLdeveloped by IIPR
14	IPC 14-133	IIPR, Kanpur	Phule G 05/IPC 17-29	-	ABLdeveloped by IIPR
15	IPC 15-12	IIPR, Kanpur	GNG 1581/ILWC 141	-	ABLdeveloped by IIPR
16	IPC 15-16	IIPR, Kanpur	IPC 09-50/IPC 07-88	-	ABLdeveloped by IIPR
17	IPC 15-35	IIPR, Kanpur	KWR 108/ICC7110	-	ABLdeveloped by IIPR
18	IPC 15-39	IIPR, Kanpur	KWR 108/ICC7110	-	ABLdeveloped by IIPR
19	IPC 15-57	IIPR, Kanpur	HC 5/ILWC 115	-	ABLdeveloped by IIPR
20	IPC 15-95	IIPR, Kanpur	HC 5/ILWC 115	-	ABLdeveloped by IIPR
21	IPC 15-108	IIPR, Kanpur	HC 5/EC 556270	-	ABLdeveloped by IIPR
22	IPC 15-113	IIPR, Kanpur	GNG 1581/ILWC 21	-	ABLdeveloped by IIPR
23	IPC 15-132	IIPR, Kanpur	GNG 1581/ILWC 237	-	ABLdeveloped by IIPR
24	IPC 15-146	IIPR, Kanpur	GNG 1581/ILWC 21	-	ABLdeveloped by IIPR
25	IPC 15-147	IIPR, Kanpur	BG 256/IPC 04- 52	-	ABLdeveloped by IIPR
26	IPC 15-165	IIPR, Kanpur	GNG 469/ILWC 21	-	ABLdeveloped by IIPR
27	IPC 15-185	IIPR, Kanpur	IPC 06-11/ILWC 21	-	ABLdeveloped by IIPR
28	IPC 15-202	IIPR, Kanpur	KWR 108/ILWC 115	-	ABLdeveloped by IIPR
29	IPC 16-06	IIPR, Kanpur	IPC 2009-50/IPC 07-88	-	ABLdeveloped by IIPR
30	IPC 16-15	IIPR, Kanpur	GNG 1581/ILWC 115	-	ABLdeveloped by IIPR
31	IPC 16-25	IIPR, Kanpur	KWR 108/ICCC 15614	-	ABLdeveloped by IIPR
32	IPC 16-26	IIPR, Kanpur	IPC 06-27/JG 03-14-16	-	ABLdeveloped by IIPR
33	IPC 16-27	IIPR, Kanpur	ICARDA 37125	-	ABLdeveloped by IIPR
34	IPC 16-39	IIPR, Kanpur	IPCK 02-29/ILWC 21	-	ABLdeveloped by IIPR
35	IPC 16-52	IIPR, Kanpur	IPCK 02-29/ILWC 21	-	ABLdeveloped by IIPR
36	IPC 16-53	IIPR, Kanpur	BPM/IPC 06-11	-	ABLdeveloped by IIPR
37	IPC 16-95	IIPR, Kanpur	HC 5/JG 315	-	ABLdeveloped by IIPR
38	IPC 16-136	IIPR, Kanpur	ILWC 21/IPC 08-57	-	ABLdeveloped by IIPR
39	IPC 16-184	IIPR, Kanpur	BG 256/JG 03-14-16	-	ABLdeveloped by IIPR
40	IPC 16-231	IIPR, Kanpur	KWR 108/ICC 1205	-	ABLdeveloped by IIPR
41	IPC 16-236	IIPR, Kanpur	IPC 06-11/ICC 96030	-	ABLdeveloped by IIPR
42	IPC 17-04	IIPR, Kanpur	JG 16/IPC 08-57	-	ABLdeveloped by IIPR
43	IPC 17-10	IIPR, Kanpur	KWR 108/EC 600098	-	ABLdeveloped by IIPR
44	IPC 17-21	IIPR, Kanpur	JG 16/IPC 08-57	-	ABLdeveloped by IIPR
45	IPC 17-35	IIPR, Kanpur	JG 315/JG 03-14-16	-	ABLdeveloped by IIPR
46	IPC 17-37	IIPR, Kanpur	IPCK 04-29/ILWC 179	-	ABLdeveloped by IIPR
47	IPC 17-47	IIPR, Kanpur	IPC 09-50/ICC 14778	-	ABLdeveloped by IIPR
48	IPC 17-53	IIPR, Kanpur	JG 315/JG 03-14-16	-	ABLdeveloped by IIPR
49	IPC 17-54	IIPR, Kanpur	IPC 08-57/ICC 1205	-	ABLdeveloped by IIPR
50	IPC 17-67	IIPR, Kanpur	GNG 469/ICC5434	-	ABLdeveloped by IIPR
51	IPC 17-70	IIPR, Kanpur	IPC 08-57/PA 1108	-	ABLdeveloped by IIPR

52	IPC 17-71	IIPR, Kanpur	ICC 1205/ICC 10945	-	ABLdeveloped by IIPR
53	IPC 17-78	IIPR, Kanpur	IPC 08-57/PA 1108	-	ABLdeveloped by IIPR
54	IPC 17-88	IIPR, Kanpur	IPC 06-127/ILWC 145	-	ABLdeveloped by IIPR
55	IPC 17-102	IIPR, Kanpur	WR 315/IPC 10-116	-	ABLdeveloped by IIPR
56	IPC 17-110	IIPR, Kanpur	ICC 5434/ICC 1205	-	ABLdeveloped by IIPR
57	IPC 17-114	IIPR, Kanpur	IPC 08-57/ICC 1164	-	ABL developed by IIPR
58	IPC 17-129	IIPR, Kanpur	GNG 1581/ICC 7110	-	ABL developed by IIPR
59	IPC 17-141	IIPR, Kanpur	C 8/HC 5	-	ABL developed by IIPR
60	IPC 17-143	IIPR, Kanpur	IPCK 02-29/ILWC 245	-	ABL developed by IIPR
61	IPC 17-166	IIPR, Kanpur	KWR 108/ICC 4958	-	ABL developed by IIPR
62	IPC 17-174	IIPR, Kanpur	IPC 08-57/ILWC 245		ABL developed by IIPR
63	IPC 17-185	IIPR, Kanpur	GNG 1581/ICC 14778	-	ABL developed by IIPR
64	IPC 17-189	IIPR, Kanpur	ICC 1164/ICC 10945	-	ABL developed by IIPR
65	IPC 17-196	IIPR, Kanpur	ICC 1205/ICC 8522	-	ABL developed by IIPR
66	IPC 17-207	IIPR, Kanpur	JG 11/PA 1108	-	ABL developed by IIPR
67	IPC 17-213	IIPR, Kanpur	IPC 06-11/DCP 92-3	-	ABL developed by IIPR
68	IPC 17-245	IIPR, Kanpur	GNG 1581/ICC 15614	-	ABL developed by IIPR
69	IPC 17-249	IIPR, Kanpur	IPC 06-11/ILWC 249	-	ABL developed by IIPR
70	IPC 17-253	IIPR, Kanpur	IPC 06-11/PA 1108	-	ABL developed by IIPR
71	IPC 17-256	IIPR, Kanpur	IPC 08-57/ILWC 245	-	ABL developed by IIPR
72	IPC 17-303	IIPR, Kanpur	JG16/ICC 1205	-	ABL developed by IIPR
73	IPC 17-308	IIPR, Kanpur	HC 5/ILWC 21	-	ABL developed by IIPR
74	IPC 17-318	IIPR, Kanpur	ICC 1205/JG 03-14-16	-	ABL developed by IIPR
75	IPC 17-351	IIPR, Kanpur	IPC 06-11/IPC 04-52	-	ABL developed by IIPR
76	IPC 17-354	IIPR, Kanpur	IPCK 02-29/ILWC 21	-	ABL developed by IIPR
77	IPC 17-358	IIPR, Kanpur	GNG 469/ILWC 21	-	ABL developed by IIPR
78	IPC 17-361	IIPR, Kanpur	IPC 09-50/IPC 07-88	-	ABL developed by IIPR
79	IPC 17-373	IIPR, Kanpur	IPC 08-57/WR 315	-	ABL developed by IIPR
80	IPC 17-377	IIPR, Kanpur	IPC 06-11/ICC 96030	-	ABL developed by IIPR
81	IPC 18-28	IIPR, Kanpur	IPC 06-88/ILWC 179	-	ABL developed by IIPR
82	IPC 18-37	IIPR, Kanpur	IPC 06-88/ILWC 179	-	ABL developed by IIPR
83	IPC 18-38	IIPR, Kanpur	HC 5/DCP 92-3	-	ABL developed by IIPR
84	IPC 18-40	IIPR, Kanpur	IPC06-11/PA 1108	-	ABL developed by IIPR
85	IPC 18-48	IIPR, Kanpur	ILWC 21/IPC 08-57	-	ABL developed by IIPR
86	IPC 18-52	IIPR, Kanpur	IPC 06-88/ILWC 179	-	ABL developed by IIPR
87	IPC 18-55	IIPR, Kanpur	GNG 1581/IPC 04-52	-	ABL developed by IIPR
88	IPC 18-56	IIPR, Kanpur	IPC 06-11/ICC 96030		ABL developed by IIPR
89	IPC 18-59	IIPR, Kanpur	GNG 1581/IPC 04-52	-	ABL developed by IIPR
90	IPC 18-63	IIPR, Kanpur	IPC 10-63/IPC 08-57	-	ABL developed by IIPR
91	IPC 18-69	IIPR, Kanpur	KWR 108/ICC 1205	-	ABL developed by IIPR
92	IPC 18-80	IIPR, Kanpur	GNG 1581/IPC 04-52	-	ABL developed by IIPR
93	IPC 18-90	IIPR, Kanpur	GNG 1581/IPC 04-52	-	ABL developed by IIPR
94	IPC 18-117	IIPR, Kanpur	IPC 12-122/IPC 10-63	-	ABL developed by IIPR
95	IPC 18-121	IIPR, Kanpur	JG 62/JG 03-14-16	-	ABL developed by IIPR
96	IPC 18-129	IIPR, Kanpur	IPC 08-11/ICC 7110	-	ABL developed by IIPR
97	IPC 18-131	IIPR, Kanpur	GNG 1581/ICC 15614	-	ABL developed by IIPR
98	IPC 18-132	IIPR, Kanpur	IPC 06-127/ILWC 245	-	ABL developed by IIPR
99	IPC 18-136	IIPR, Kanpur	IPC 08-11/ICC 14778	-	ABL developed by IIPR
100	IPC 18-150	IIPR, Kanpur	IPC 06-127/ILWC 245	-	ABL developed by IIPR
101	IPC 18-154	IIPR, Kanpur	BG 212/JG 03-14-16	-	ABL developed by IIPR
102	IPC 18-168	IIPR, Kanpur	JG 16/ICC 92944	-	ABL developed by IIPR
103	JG 11	JNKVV, Jabalpur	(PG5/Narsinghpur/ICCC37]ICCX-860263-BF-BP-91BP	1999	SZ (Rainfed/irrigated)
104	**JG 14 (CH)**	JNKVV, Jabalpur	[(GW5/7//P327)///ICCL83149]	2008	MP (Late Sown)
105	JG 74	JNKVV, Jabalpur	Selection from Genetic Stock	1983	Bihar, WB, East MP (late

					Sown)
106	JG 130	JNKVV, Jabalpur	[(PG5/Narsinghpur bold)/JG 74]	2002	MP (Rainfed/irrigated)
107	K 850	CSAUT, Kanpur	Banda local/Etah bold	1978	UP (irrigated)
108	NBeG 3	Nandyal	A 1/ICC 4958	2013	Andhra Pradesh
109	PG 5 (Vishwas)	MPKV Rahuri	B 110/N31	1985	Central Zone
110	RSG888 (Anubhav)	RARI, Durgapura	RSG 44/E100YM	2002	NWPZ (Rainfed)
111	RSG 991 (Aparna)	RARI, Durgapura	K 850/RSG515	2007	Rajasthan
112	Sadabahar	CSAUT, Kanpur	Hima/L 245	1992	UP (Irrigated)
113	VAIBHAV	IGKV, Raipur	Selection from Germplasm of ICC91106	2001	Chhattisgarh,MP (Rainfed)



Picture. 1 Weekly min and max temp, rainfall, relative humidity (%), and sunshine hours

Results And Discussion:

Statistical analysis of the data revealed that analysis of variance for different traits assessed under all three different sown conditions i.e., TS, LS and VLS cropping environments during rabi 2019-20 and rabi 2020-21 exhibited highly significant differences among the test entries along with the checks (Table no. 2). Variation due to blocks have also been observed to be significant for almost all the traits under all three cropping environments. The error variations were insignificant for all the traits under observations, even under all the three cropping conditions during rabi 2019-20 and 202-21 traits. This provides significant opportunity for identification and utilization of the genetic variability for phenotypic and genotypic characterization and deciding the breeding strategies for terminal heat tolerant chickpea genotypes. The results are in a close agreement with results reported by Krishnamurthy et al., (2011), Kumar et al. (2012), Baber et al. (2012), Kumar et al. (2017), and Agarwal et al. (2018).

Descriptive analysis like range, mean, standard error and standard deviation (SD) for various trait such phenological traits, plant architectural traits and yield attributing traits were evaluated under timely sown (TS), Late sown (LS) and Very Late Sown (VLS) conditions during Rabi 2019-20 and 2020-21 showed significant and high magnitude of genetic variation. Wide range of variability was noted for six phenological traits under study such as DFI, DFF, DPI, DFP, DMIand DMduring 2019-20 and 2020-21under TS, LS and VLS cropping environment respectively. Variations for two plant architectural traits such as PHT (cm) (43-88 days,36-76 and 31-58 days)&(36-88,25-69 and 31-62); and PB (5-7,3-6, and2-5)&(4-7, 3-6, and 2-5)have were recorded during 2019-20 and 2020-21under TS, LS and VLS cropping environment respectively.Similarly, variations for nine yield attributing trait such as BY (gm), PY (gm), BMPP(gm), SYP (gm), SPP, FPP, UFP, HSW (gm), yield (kg/ha) and HI (%)under TS, LS and VLS cropping environment have also been recorded for both the cropping year respectively(Table 3 and 4). Thus, the presence of variations observed in all the phenological, plant architectural and yield attributing traits under the study could be used as selection criteria for selecting most promising line for terminal heat stress tolerance in chickpea. Similar results were reported by Krishnamurthy et al, Upadhyaya et al. (2011), Babbar et al. (2012), Kumar et al. (2015), Jha et al. (2015), Desai et al. (2017), Kumar et al. (2017), Agrawal et al. (2018) and Paul et al. (2018).

Genetic parameters of variability have been presented in **Table no. 5.**All characters under study have shown a higher magnitude of PCV than their corresponding GCV suggesting the impact of environment on the expression of these traits. The smaller difference between PCV and GCV indicates a greater contribution of genotypes for the expression of these characters. In the present study highest genotypic and phenotypic coefficient of variationwas observed for UFP, SYP (g), PB, Y (kg/ha), PY (g), HI (%), BMP (g), HSW (g) and FP (**Table no. 5, Fig. 3**).Selection for these traits would be rewarding under stress conditions because the response to selection is directly proportional to the variability present within the experimental material (Velpula*et al.*,2022). Similar magnitudes of GCV and PCV were also observed by Summerfield at al., (1984) and Devasiratham et al., (2015). While the traits viz., DFI, DFF, DPI, DFP, DMI, DM and PHT (cm), BY (g) and NSP exhibited the moderate to low range of GVC and PCV value under TS, LS and VLS cropping conditions During rabi 2019-20 and 2020-21. Traits heritability is also a paramount important criterion while trying to improve the yield potential and resistance to stresses of any crop plants. Traits with high heritability and directly concern with yield under heat stress condition, could be selected and further utilized in breeding programme. Highest value of heritability (%) have been observe for the traits DFI, DFF, DMI, DM, PB, Y (kg/ha), HSW (g), SYP (g), BMP (g) and FP in all three different cropping environments (**Table no. 5**) during both the experimental year ie., rabi 2019-20 and 2020-21. Similar finding has also been reported by Babbar et al. (2015), Kumar et al. (2016) and Reddy et al. (2017). Few traits such as DPI, PHT (cm) and PY (g) exhibited medium range of heritability percentage. While DFP, BY (g), HI (%), UFP and NSP showed low range of heritability percentage. Highest value of Genetic Advance (GA) as percent of mean have been recorded for the traits PY (g) and Y (Kg /ha). While rest of the traits exhibited medium to low range of Genetic advance for almost all the traits under study in all three cropping conditions (I. e., TS, LS and VLS trials) during both the experimental year i.e., rabi 2019-20 and 2020-21.

The correlation coefficient is a statistical measure to estimate the degree and direction of the association between two variables. In the current study correlation coefficient analysis have been estimated for the Correlation values (Table 6) for all three different trials viz Timely sown (TS), Late sown (LS) and Very Late sown (VLS) conducted in Rabi 2019-20 and 2020-2021.An understanding of the inter-relationships among various characters and the magnitude of their contribution towards seed yield is required to plan the most effective selection criteria for improving seed yield. ThePearson correlation coefficients of pooled data were calculated for Eighteen morphological traits which includes Six phenological traits viz., days to initial flowering (DFI), days to 50% flowering (DFF), days to initial podding (DPI), days to 50% podding (DFP), days to maturity initiation (DMI) and days to maturity (DM)**;** Two plant architectural traits viz., plant height (PHT) and primary branch per plant (PB)**;** Ten yield and yield attributing traits viz., plot yield (g) (PY), yield (kg/ha) (Y), hundred seed weight (g) (HSW), biological yield per plant (g) (BY), seed yield per plant (g) (SYP), biomass per plant (g) (BMP), harvest index % (HI). filled pods (FP), empty pods (EP) and seeds per pod (SPP)presented in **Table 6**. The major yield contributing traits such as DFF, PHT (cm), PB, SYP (g), PY (g), Y (g), HSW (g), BY (g)and HI (%) have significantly correlated with all the traits except UFP and NSP (Table no. 6). The PY (g)exhibited strong positive correlation with Y (Kg/ha) (0.857^{**} and 0.964^{**}); HSW (g) (0.544^{*} and 0.412^{*}); BY (g) (517^{*} and 0.856^{**}); SYP (g) ($0.628^{**}$and 0.506^{*}); BMP (g) (0.553^{*} and 0.494^{*}); HI (%) (0.459^{*} and 0.706^{**}). Similarly, another chief yield contributing traits like SPY (g) is also positively correlated BMP (g) (0.536* and 0.682**); HI (%) (0.678** and 0.779**); FP (0.774** and 0.964**) and NSP (0.456* and 0.503*)except UFP (Table no. 6). Similar finding has also been recorded by Singh et al. (20121), Jha et al. (2016) and **Tadesse et al. (2016).**

Kaiser's Rule for PCA is a method for determining the optimal number of principal components to retain based on the eigenvalues, with a suggested threshold of retaining only those components with eigenvalues greater than or equal to 1. Out of Eighteen PCs, first ten PCs have more than 1 eigenvalues for all three separate trials (i.e., TS. LS and VLS) conducted during rabi 2019-20 and 2020-21. The eigenvalue is a measure of the amount of variance explained by each principal component, with larger eigenvalues indicating a greater amount of variance explained. PC1 to PC11reveals(95.50%, 94.87% and 90.51%) and (95.56%, 96.58% and 96.76%) of total percentage of varianceunder TS, LS and VLS trial conducted during 2019-20 and 2020-21.Maximum percentage of variance for all 113 diverse chickpea genotypes has been recorded for PC1(26.83, 26.63&31.46 in 2019-20; 29.87, 35.15&30.2 in 2020-21) and PC2 (24.19, 22.81 & 12.66 in 2019-20; 18.96, 15.43 & 17.4 in 2020-21) for all three separate trials i.e., TS, LS and VLS (**Table no. 7**).Therefore, consideration should be given to these major components showing maximum value (Table no. 7) in selecting parents to introgression of genes for greater yield. Scree plot of principal component analysis of all three separate trials (TS, LS and VLS) conducted during both the consecutive year (i.e., 2019-20 and 2020-21) clarify the percentage of variation for the concerned principal components (Figure no. 4).

Conclusions:

The present investigation revealed the presence of genetic variability for major economically important traits such as DFF, DM, PHT (cm), PB, BY (g), PY (g), SYP (g), HSW (g), FP, UFP and HI (%). Study also can be successfully utilized in breeding to improve seed yield in chickpea under changing cropping conditions. The study also indicates that most of the major yield attributing traits [PHT (cm), PB, BY (g), BM (g), SYP (g), PY (g), K (Kg/ha), HSW (g), FP and HI (%) have positive and significant association with each other. Means indirect selection of these traits for genetic enhancement of yield under changing environmental conditions (i.e., TS, LS and VLS) would be rewarding. Principal component analysis of all the trials conducted during rabi 2019-20 and 2020-21 reveals that first 10 PCs includes more than 95% of variance for all three separate trials conducted for two consecutive years. So, selection of these components for trait manipulation regarding enhance yield performance may cover most of the variances which is prerequisites for starting any judicious breeding programme.

Table No. 1 ANOVA For yield and its contributing traits under Timely Sown (TS), Late Sown (LS) & Very Late Sown (VLS) Trial 2019-20

Mean Sum of Square

Source	ENV	Df	BMPP	BYPP	DFF	DFI	DFP	DM	DMI	DPI	FP	HI	HSW	NSP	PBP	PHT	PY	SYPP	UFP	Yield
Treatment	TS	112	53.42**	67.35	68.84**	83.39**	48.02*	47.39**	64.83**	62.16*	126.56*	60.15*	10.36**	0.3	0.35*	151.43**	50165.31*	30.42*	2.96*	1016081.35**
	LS	112	67.12**	72.75**	51.71*	55.03*	62.55*	130.09**	70.66**	63.65*	53.37**	34.27*	18.07**	0.1	0.62**	85.04*	26042.48*	25.81**	2.97*	648603.11**
	VLS	112	47.86*	39.21*	47.83*	44.03*	74.18**	67.2**	23.25*	9.54	42.92*	52.58*	15.62**	0.2	2.33*	37.68	317475.31**	5.39 n	4.98	239197.05
Check	TS	4	90.26**	217.72*	249.59**	197.08**	304.02**	163.8**	189.08**	347.77**	251.96*	47.73*	46.75**	0.23**	0.44**	77.31**	348237.2**	51.98*	5.11**	40838180.85**
	LS	4	51.28*	75.97**	67.35*	57.92**	97**	98.13**	67.63**	57.33*	184.39**	64.61*	25.71**	0.12*	0.73*	195.03*	158292.4**	20.63	3.53**	4010016.86**
	VLS	4	49.51*	29.29*	37.35**	47.73*	53.47*	57.17**	27.4*	34.25**	62.77*	49.08*	16.2**	0.11*	1.04	39.17	51434.5**	10.63*	3.92**	1089249.62**
Test vs. Check	TS	1	458.68**	386.24*	439.64**	533.76**	329.11**	60.128	51.22*	484.09**	1966.5**	62.68**	13.35**	0.13*	1.18**	4838.28**	586181.05*	45.45*	15.87**	23842615.74**
	LS	1	342.54**	195.83*	126.42*	105.43*	219.43*	362.89**	255.98*	333.44**	86.23*	62.45*	6.6	0.16*	6.41**	410.05*	412241.42**	26.31**	1.36	7444759.09*
	VLS	1	347.5**	223.89**	335.66**	362.29**	420.64**	370.55**	178.47*	0.18	338.57**	72.92*	41.75**	0.16*	5.01**	116.85**	601584.06**	65.13**	40.23**	8275724.13**
Test	TS	107	48.26**	58.75*	58.62**	74.93**	65.82*	43.48**	60.31**	67.54*	204.67*	40.61	9.07**	0.05	0.36*	110.4**	328942.85*	29.48*	7.82**	656166.1*
	LS	107	54.48*	60.92*	50.43*	54.71*	70.07**	68.36*	50.44*	42.67	48.17**	32.87*	17.47**	0.04	0.56**	77.89*	210947.17**	25.77**	3.09**	522044.13*
	VLS	107	39.99*	47.77**	46.75**	52.88*	64.15**	46.79*	23.98*	8.71	39.42*	51.87*	15.2**	0.01	1.29*	37.82	2101746.85**	4.64 n	4.69	532311.65*
Block	TS	3	38.21*	40.22*	45.56**	41.25*	53.85*	32.21*	69.93**	41.23*	77.27*	26.16*	5.61*	0.02	3.41**	74.09*	313573.52*	21.95*	5.018*	344055.62*
	LS	3	62.29**	55.3**	42.72*	37.97	75.17**	39.65	42.58*	51.35**	55.14*	37.85**	12.01*	0.02	2.54*	128.86**	211035.79*	23.79*	3.88*	773786.93**
	VLS	3	26.52	30.45*	36.69*	27.6	45.52*	64.87**	24.01*	42.07*	63.07*	23.7*	10.3*	0.01	1.43*	130.09**	338458.18*	22.76*	6.35*	373085.13*
Error	TS	12	12.76	43.2	8.28	13.11	15.3	9.23	7.3	21.1	47.98	18.7	2.46	0.03	0.11	9.43	18941.6	9.86	1.49	260643.21
	LS	12	29.78	31.21	16.31	16.99	32.35	37.76	43.92	48.25	13.42	12.1	8.49	0.13	0.16	51.21	10217.59	16.77	1.17	186199.22
	VLS	12	12.55	27.21	25.13	31.63	38.63	33.28	18.89	22.12	13.53	32.9	9.67	0.01	0.31	36.47	8034.1	2.47	2.45	110464.09

Table No. 2 ANOVA For yield and its contributing traits under Timely Sown (TS), Late Sown (LS) & Very Late Sown (VLS) Trial 2020-21

			Mean Sum of Square																		
Source	ENV	**Df**	**BMPP**	**BYPP**	**DFF**	**DFI**	**DFP**	**DM**	**DMI**	**DPI**	**FP**	**HI**	**HSW**	**NSP**	**PBP**	**PHT**	**PY**	**SYPP**	**UFP**	**Yield**
Treatment	TS	112	74.84**	86.22 *	53.44 *	66.95**	27.26 *	59.71*	52.95**	40.55**	63.69	15.1	9.57**	0.04	3.5*	153.99**	29524.91**	13.18 **	0.96	563396.92 **
	LS	112	48.23 *	73.09 *	56.19 *	64.11**	67.47**	75.06**	42.75*	43.51*	18.04	22.16*	17.07*	0.06	3.45*	73.92*	16410.7 **	8.26 *	3.9**	333538.56 **
	VLS	112	60.58**	46.56	42.42*	40.9*	66.1**	6.75	64.88**	58.03**	18.86 *	38.42**	15.35**	0.02	0.43	75.07*	6514.58 *	5.22 *	4.05*	242500.13 *
Check	TS	4	61.12*	126.42 *	243.38**	236.92	106.65 **	42.07	57.88**	150.8**	43.81	28.42*	15.22**	0.17 **	4.53*	43.42*	61602.07**	37.34 **	1.26*	2161297.68 **
	LS	4	65.64*	194.85**	138.93**	141.68**	53.62	33.4	47.26*	72.58**	5.86	33.2*	13.21*	0.13 *	4.61**	44.22*	39600.95 **	41.11 **	2.88*	858681.71 **
	VLS	4	56.64*	84.21 *	66.85 *	94.15**	52.51*	69.17**	67.63**	62.64**	41.82**	48.64**	20.75**	0.21**	4.93**	66.6*	55227.92**	15.38**	1.09	418850.69**
Test vs. Check	TS	1	341.9**	253.14 *	231.31 **	382**	141.83 **	118.05**	233.72**	279.14**	408.54**	48.25*	21.16**	0.27**	12.04**	317.29**	206158.48**	89.06 **	2.99**	5294170.22 **
	LS	1	115.56*	194.06 *	630.21**	853**	228.48**	321.2**	166.66*	452.97**	208.64 **	215.7 **	38.69**	0.04*	5.45**	288.97**	210533.56**	133.94 **	6.04*	7239230.58 **
	VLS	1	112.67**	160.05*	244.76**	89.66**	90.79**	227**	173.8*	216.91**	222.93**	410.97**	229.3**	0.21**	6.35**	242.99**	99434.17**	121.38**	62.07**	2377474.72**
Test	TS	107	45.56**	83.15 *	44.68 *	57.66**	23.22*	30.07*	43.69*	34.2*	30.84*	44.29**	9.25**	0.14**	5.51**	156.6**	26674.98 **	21.57 *	0.93	459449.48 **
	LS	107	47.98**	67.41 *	47.73 *	53.84**	35.08**	44.32*	52.17**	38.6*	46.7**	39.93*	17.19*	0.22**	2.39*	274.89**	13729.54 **	25.86**	1.86**	249367.87 **
	VLS	107	39.62*	44.09*	50.55*	47.52*	16.37*	56.47*	34.23	47.86**	36.1**	44.37**	45.49**	0.11*	2.35*	76.99*	26530.72 *	23.75*	3.62**	215954.55 *
Block	TS	3	47.4**	34.07*	59.49**	36.94*	66.38**	31.08*	61.45**	54.06**	85.52**	75.16**	48.31*	0.03	1.02*	64.52**	342112.6*	21.42*	4.89**	32184200.4**
	LS	3	55.51**	49.3**	37.38*	42.65**	46.72*	32.48*	44.81*	40.56*	63.73**	67.6**	55.62**	0.07	2.2*	56.19*	21416.18*	23.05*	3.18*	107509.33**
	VLS	3	11.34	55.47**	47.85**	52.46**	30.98	26	55.73**	49.65**	30.92*	35.27*	63.06**	0.04	1.92*	83.84**	238841.2*	10.81	2.55*	1004802.98**
Error	TS	12	20.6	27.99	18.12	13.23	9.71	8.5	12.15	16.23	29.25	7.99	1.92	0.01	0.31	90.83	3753.81	3.63	0.78	77169.28
	LS	12	20.49	26.13	17.35	9.75	20.33	23.22	21.53	24.49	12.13	10.62	4.55	0.01	0.38	43.38	1565.35	3.09	0.93	46626.86
	VLS	12	18.57	23.47	12.41	11.54	13.19	8.08	21.98	12.64	6.34	10.32	2.68	0.01	0.29	55.98	2579.16	1.88	1.64	73546.76

Table 3. Descriptive Statistics (2019-20)

	DFI			DFF			DPI			DFP			DMI			DM		
	TS	LS	VLS	TS	LS	VLS	TS	LS	VLS	TS	LS	VLS	TS	LS	VLS	TS	LS	VLS
Min	51.25	41.99	43.39	57.96	48.95	51.86	66.88	62.62	53.1	76.06	69.61	58.71	96.16	84.05	56.88	107.14	100.47	91.9
Max	90.25	78.44	64.04	95.91	86.75	66.31	103.91	94.73	73.1	108.54	103.81	79.46	129.91	114.85	96.97	140.19	124.67	104.5
Mean	71.83	64.18	54.54	79.44	72.17	58.36	87.28	79.91	62.8	95.51	87.86	67.97	116.7	102.44	89.7	129.46	114.72	99.46
SE	0.81	0.68	0.33	0.72	0.66	0.25	0.68	0.62	0.32	0.57	0.66	0.34	0.72	0.58	0.46	0.61	0.5	0.26
CV (%)	5.09	6.45	6.26	3.65	5.62	3.88	5.3	8.73	7.49	4.12	6.5	4.33	2.31	5.69	3.32	2.35	5.37	3.67
SD	8.56	7.28	3.53	7.69	7.01	2.69	7.19	6.59	3.38	6.01	7.02	3.65	7.68	6.12	4.87	6.47	5.27	2.77
Skewness	0.65**	0.66**	-0.45*	0.53**	0.77**	0.53**	0.42**	0.52**	-0.03	-0.6*	0.43	0.78**	-0.61**	0.^{52*}	-4.84**	-1.01**	0.6**	-0.26
Kurtosis	5.71**	7**	4.47*	3.71**	6.76*	7.14*	2.52 ns	5.79**	3.33	6.09**	6.91**	4.15*	2.57	3.06*	33.08**	7.53**	2.81	2.53
	PHT (cm)			**PB**			**BY (g)**			**PY**			**BMP (g)**			**SYP (g)**		
	TS	**LS**	**VLS**	**TS**	**LS**	**VLS**	**TS**	**LS**	**VLS**	**TS**	**LS**	**VLS**	**TS**	**LS**	**VLS**	**TS**	**LS**	**VLS**
Min	43.79	36.87	31.1	5.06	3.3	2.08	45.42	38.06	24.43	454.15	352.76	172.54	22.24	23.57	16.39	9.63	7.11	5.06
Max	88.37	76.77	58.9	7.64	6.69	5.23	82.09	78.78	52.99	1357.45	1103.46	730.75	66.17	49.49	44.13	29.93	27.61	14.11
Mean	64.8	55.29	46.28	6.37	4.81	3.47	64.74	55.04	38.6	927.29	721.14	371.29	45.38	37.64	29.52	20.84	15.95	9.08
SE	1.03	0.85	0.63	0.06	0.07	0.06	0.78	0.7	0.5	19.5	14.22	11.22	0.68	0.57	0.42	0.5	0.38	0.2
CV (%)	4.88	13.07	13.08	5.15	8.13	15.68	10.24	10.22	10.63	14.74	13.91	22.84	7.97	14.69	11.92	15.21	16.29	16.9
SD	10.96	9.01	6.73	0.6	0.76	0.59	8.27	7.43	5.3	207.26	151.18	119.31	7.24	6.07	4.5	5.35	4.02	2.17
Skewness	-0.35*	0.77**	0.41**	-0.24	0.32	0.2	-0.4	0.67**	0.57**	-0.38**	0.27	0.39**	-0.6**	0.56*	0.26	-0.08	0.48*	0.38**
Kurtosis	2.04**	2.27*	2.12**	2.17**	5.5**	2.63	6.62**	8.51**	13.23**	2.53	2.71	23.29**	3.8	2.31*	3.9	1.77**	4.58**	2.23*
	SPP			**HSW (g)**			**FPP**			**UFP**			**HI (%)**			**Y (Kg/ha)**		
	TS	**LS**	**VLS**	**TS**	**LS**	**VLS**	**TS**	**LS**	**VLS**	**TS**	**LS**	**VLS**	**TS**	**LS**	**VLS**	**TS**	**LS**	**VLS**
Min	1.85	1.55	1.21	14.19	12.79	10.78	37.74	34.3	16.92	0	0.38	3.62	15.89	15.14	12.05	1824.56	1300.44	337.78
Max	2.4	1.88	1.44	28.09	26.42	22.03	93.52	69.03	47.1	3.89	8.92	16.12	47.61	40.14	40.82	5576.68	5366.41	2660.7
Mean	1.49	1.3	1.14	20.64	18.47	15.98	60.59	50.18	31.18	1.66	4.5	8.89	31.93	28.59	23.5	3865.09	3087.62	1153.19
SE	0.02	0.02	0.01	0.28	0.26	0.23	1.11	0.65	0.58	0.09	0.17	0.23	0.57	0.52	0.46	82.49	73.01	41.09
CV (%)	12.45	14.01	9.53	7.59	11.45	10.21	11.67	7.34	11.61	40	23.96	17.94	13.53	12.07	15.14	13.25	13.87	26.99
SD	0.23	0.17	0.12	3.03	2.8*	2.4*	11.	6.96**	6.21	0.95	1.85	2.41	6.03	5.54	4.94	876.85	776.1	436.76
Skewness	0.71**	0.13**	0.33**	-0.15	0.28	-0.03	0.52**	0.65**	0.37	0.04	0.31*	0.53**	-0.08	0.59*	0.62**	-0.41**	0.63**	1.31**
Kurtosis	4.36*	6.56**	2.34	2.38	6.71**	2.58	4.59*	4.8*	2.45	2.39	2.82	6.2*	2.84	2.38	7.64**	2.28*	4.66*	4.62**

Table – 4. Descriptive Statistics 2020-21																		
	DFI			**DFF**			**DPI**			**DFP**			**DMI**			**DM**		
	TS	**LS**	**VLS**	**TS**	**LS**	**VLS**	**TS**	**LS**	**VLS**	**TS**	**LS**	**VLS**	**TS**	**LS**	**VLS**	**TS**	**LS**	**VLS**
Min	53.01	47.11	42.24	60.36	57.55	47.87	70.71	63.09	55.93	81.88	71.55	62.25	95.13	85.26	70.31	124.88	102.26	85.8
Max	87.01	82.71	65.04	92.91	90.95	70.47	97.71	94.24	74.83	103.88	99.55	81.45	130.32	114.26	98.36	139.57	118.06	103.6
Mean	72.16	65.91	56.24	79.9	74.59	61.63	87.45	81.79	66.88	95.45	88.47	72.66	122.17	105.16	88.36	132.81	112.53	96.01
SE	0.71	0.71	0.42	0.62	0.69	0.44	0.57	0.64	0.43	0.45	0.62	0.43	0.44	0.44	0.37	0.29	0.36	0.29
CV (%)	5.08	4.8	6.07	5.36	5.64	5.73	4.63	6.09	5.32	3.28	5.12	5	2.85	4.42	5.32	2.2	4.29	2.96
SD	7.55	7.6	4.5	6.63	7.35	4.63	6.1	6.8	4.56	4.76	6.6	4.54	4.65	4.73	3.98	3.06	3.82	3.07
Skewness	-0.45*	0.56**	0.65**	0.64**	0.53**	0.51*	-0.47*	-0.63**	-0.48*	-0.54*	-0.7**	-0.31	-2.97**	-0.96**	0.54*	-0.51*	-0.84**	-0.36
Kurtosis	2.39	5.4**	4.74*	8.86**	4.64**	2.74	2.76	6.34**	2.55	2.76	3.21	2.42	17.49**	4.75**	5.61**	2.73	7.26**	3.71
	PHT (cm)			**PB**			**BY (g)**			**PY**			**BMP (g)**			**SYP (g)**		
	TS	**LS**	**VLS**	**TS**	**LS**	**VLS**	**TS**	**LS**	**VLS**	**TS**	**LS**	**VLS**	**TS**	**LS**	**VLS**	**TS**	**LS**	**VLS**
Min	36.88	25.69	31.32	4.48	3.31	2.33	36.35	29.39	24.85	265.7	244.85	164.6	21.38	19.88	18.35	12.23	7.15	5.17
Max	88.68	69.89	62.35	7.78	6.26	5.58	79.79	64.51	52.39	997.9	724.85	541	56.26	48.76	41.68	25.73	18.29	15.04
Mean	62.37	48.01	46.03	6	4.73	3.67	55.48	45.06	36.69	556.26	395.9	285.61	37.42	33.03	28.34	18.05	12.03	8.35
SE	1.17	0.78	0.72	0.07	0.06	0.07	0.91	0.8	0.61	16.03	11.15	7.25	0.7	0.68	0.51	0.31	0.23	0.18
CV (%)	15.4	13.79	16.27	9.3	12.9	14.51	9.46	11.25	13.08	10.77	9.69	17.61	12.07	13.68	15.18	10.4	14.22	15.84
SD	12.41	8.25	7.65	0.71	0.67	0.7	9.63	8.52	6.49	170.42	118.57	77.03	7.46	7.22	5.4	3.31	2.5	1.97
Skewness	0.62**	-0.21	0.47**	0.22	0.45**	0.48*	0.66**	0.25	0.36	0.31	1.03**	1.05**	-0.21	0.19	0.57**	0.55*	0.55*	1.29**
Kurtosis	2.08**	5.24**	5.39**	7.69**	2.53	2.93*	2.46	2.35	2.62	2.36	6.3**	3.99*	2.51	2.37	7.5**	5.41*	4.76**	4.84**
	SPP			**HSW (g)**			**FPP**			**EPP**			**HI (%)**			**Y (Kg/ha)**		
	TS	**LS**	**VLS**	**TS**	**LS**	**VLS**	**TS**	**LS**	**VLS**	**TS**	**LS**	**VLS**	**TS**	**LS**	**VLS**	**TS**	**LS**	**VLS**
Min	1.02	1.02	0.94	13.63	10.81	10.31	34.5	28.49	19.76	1.45	2.72	3.56	24.11	19.43	16.61	1113.53	886.39	360.07
Max	2.04	1.63	1.44	28.46	25.64	23.21	64.33	49.59	39.89	5.69	9.43	13.63	43.37	40.56	33.35	3898.6	3010.26	2540.33
Mean	1.56	1.34	1.16	20.38	17.84	15.61	49.63	38.67	28.42	3.04	5.32	7.86	32.63	26.94	22.87	2311.47	1634.93	1272.79
SE	0.02	0.01	0.01	0.31	0.27	0.23	0.59	0.48	0.42	0.1	0.13	0.18	0.39	0.43	0.36	69.03	51.11	50.88
CV (%)	6.45	6.91	7.11	6.76	11.9	10.42	10.8	8.91	8.73	28.49	18.4	16.78	8.61	11.92	13.72	11.7	12.64	20.63
SD	0.21	0.13	0.13	3.34	2.92	2.44	6.24	5.1	4.41	1.03	1.36	1.94	4.16	4.59	3.88	733.84	543.3	540.84
Skewness	0.03	0.26	-0.17**	-0.06	0.12	0.08	-0.22	0.06	0.41	0.13	0.43	0.33	0.31	0.47*	0.72**	0.49*	1.01**	0.75**
Kurtosis	2.64	2.61	2.04**	2.22*	2.71	2.78	2.73	2.02**	2.73	2.81	2.77	3.17	11.68**	3.52*	5.88**	2.12**	7.08**	2.22*

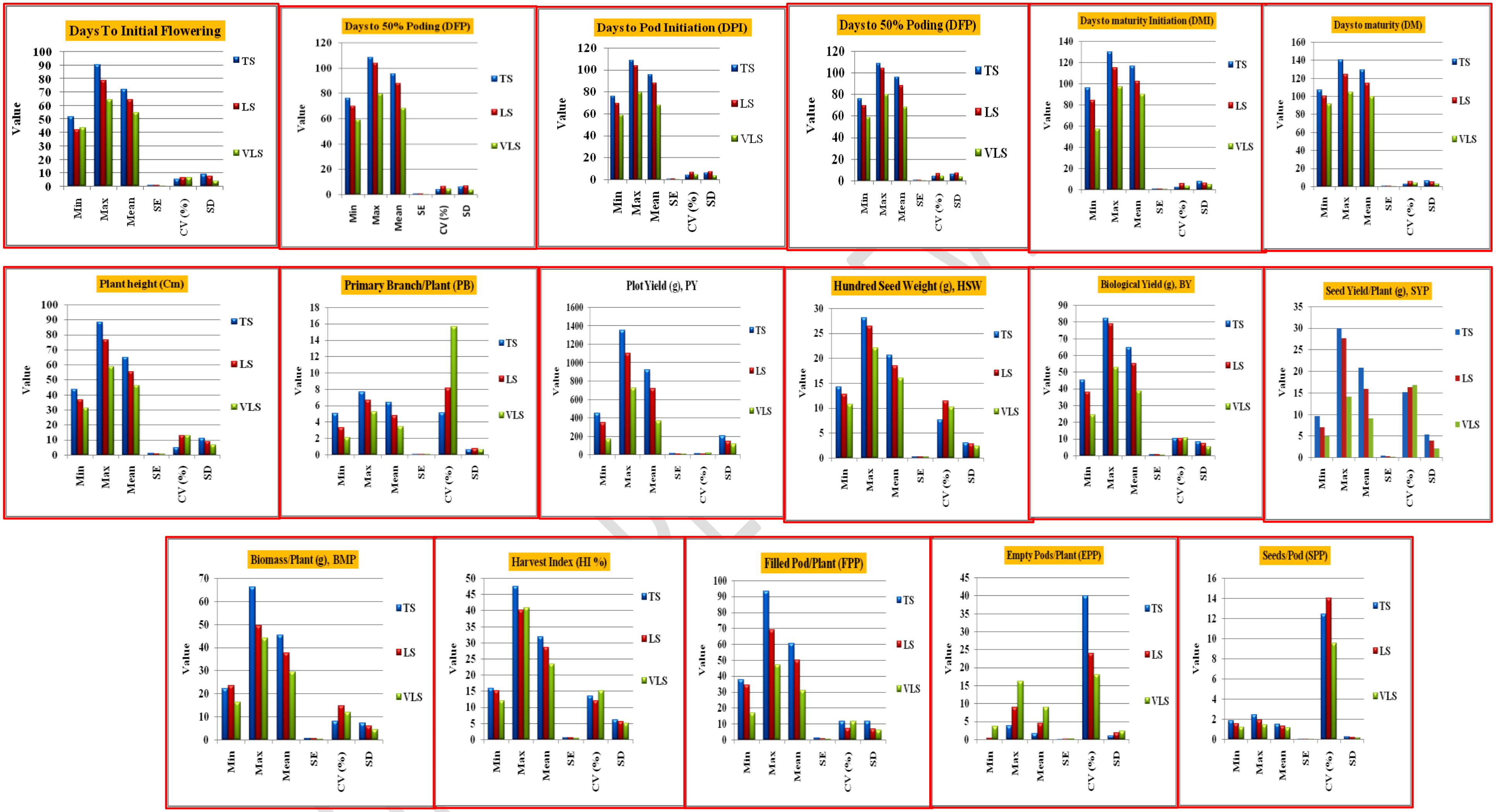


Fig. 1 Mean performance and general statistics of different traits of chickpea under Timely sown, late sown & very late sown environmentalcondition (2019-20).

Fig. 2 Mean performance and general statistics of different traits of chickpea under Timely sown, late sown & very late sown environmental condition (2020-21).

Table no. 5Genetic variability parameter results of yield and yield attributing traits under TS, LS & VLS cropping environments during rabi 2019-20 & 2020-21

Trait	GCV						PCV						hBS (%)						GA					
	2019-20			2020-21			2019-20			2020-21			2019-20			2020-21			2019-20			2020-21		
	TS	LS	VLS	TS	LS	VLS	TS	LS	VLS	TS	LS	VLS	TS	LS	VLS	TS	LS	VLS	TS	LS	VLS	TS	LS	VLS
DFI	11	9.57	12.1	6.24	5.07	4.35	12.1	11.5	16.6	10.5	11.1	17.4	82.5	69	69.7	77.1	81.9	74.1	14.73	10.52	0.72	12.07	12.4	4.95
DFF	8.93	8.09	4.18	6.45	7.39	4.63	9.64	9.84	6.45	8.37	9.26	7.35	85.9	67.7	74.25	69.4	63.6	69.6	13.56	9.91	1.28	8.2	9.07	5.7
DPI	5.89	10.6	9.46	4.85	4.59	3.42	7.9	18.17	14.7	6.69	7.6	6.32	45.6	44.7	59.6	42.5	56.6	41.3	7.91	11.92	7.34	6.34	4.68	2.55
DFP	4.74	4.79	3.46	3.85	4.34	2.45	6.27	8.05	15.5	5.05	6.69	5.57	27.3	25.4	39	38.2	42	19.4	7.07	5.17	3.03	5.78	5.14	1.62
DMI	6.24	9.56	4.33	2.78	0.76	8.78	6.65	15.39	5.46	3.98	4.48	14.27	87.9	74.2	62.9	88.7	64.9	74.2	14.08	7.44	6.36	4.89	0.28	2.47
DM	4.52	14.7	17.5	0.94	7.56	7.56	5.09	14.64	12.62	2.39	13.36	12.65	78.8	63.7	74.4	85.6	75.3	68.3	10.71	7.23	9.34	1.02	12.7	6.87
PHT (cm)	5.51	9.34	2.51	13	11.7	12.2	16.2	16	13.3	20.1	18	16.4	41.5	34.3	33.58	42	42.1	61.8	19.82	6.24	0.45	10.84	7.51	4.28
PB	17.9	23.3	19.2	27.4	2.3	16.6	19.5	25.6	25.6	31.9	13.3	16.2	70.3	72.1	69.5	68.2	63	66.5	0.87	1.12	8.56	6.56	0.04	7.2
PY (g)	15.3	14.4	14	27.2	17.9	22.5	21.3	20.1	27.9	29.4	29.6	28.3	51.4	51.2	55.2	45.9	48.6	50.5	209.09	152.9	53.98	289.5	214	101
Y (Kg/ha)	16.3	18.8	12.8	26.8	27.5	29.7	21	23.4	31.5	29.3	30.5	36.5	60.3	64.3	66.5	83.2	81.3	65.9	1007.3	958.9	123.9	1164	838	632
HSW (g)	12.5	13.3	10.1	13.3	12.1	10.7	14.6	14.8	14.4	14.9	15	15	72.8	39.9	49.2	79.2	36.8	51.3	4.52	2.25	2.33	4.97	2.04	2.48
BY (g)	6.09	18.1	8.42	13.4	14.3	12.4	11.8	23	13.7	16.4	18.2	18.1	26.5	38.7	38	36.3	21.2	46.8	4.19	5.7	4.13	12.48	10.4	7.41
SYP (g)	21.3	28.8	26.2	15.6	13.8	16.4	26.1	34.9	23.7	18.8	20.1	23.2	66.5	67.1	66.8	68.6	47.3	49.9	7.45	4.68	2.08	4.81	2.36	1.99
BMP (g)	13.1	5.76	9.24	13.2	15.9	12.3	15.3	15.6	15.1	17.9	21	19.5	73.6	13.6	37.2	54.2	57.3	39.4	10.54	1.65	3.43	7.5	8.19	4.49
HI (%)	14.7	15.9	12.7	7.69	11.3	8.8	20	20.1	19.9	11.6	16.6	16.6	54	53.2	41	44.1	46.7	58.2	7.09	7.47	3.95	3.44	4.3	2.2
FP	12.4	11.8	16.3	23.7	25.5	8.99	16.9	13.8	20.1	29.2	27.57	24.1	74.2	72.1	65.7	67.3	67.4	65.6	11.43	10.33	8.51	13.76	5.31	5.02
UFP	34.5	30.8	16.9	12.9	18.1	17.9	54.5	39.1	24.4	31.7	25.7	24.2	39.9	32.1	37.9	16.6	19.9	24.5	0.74	2.25	2.14	0.33	1.4	2.14
NSP	9.52	9.56	3.79	10.3	6.59	6.97	15.8	12	10.3	12.1	10.6	10	36.5	26.4	13.4	31.4	37.5	38.5	0.18	2.67	0.03	0.28	0.13	0.12

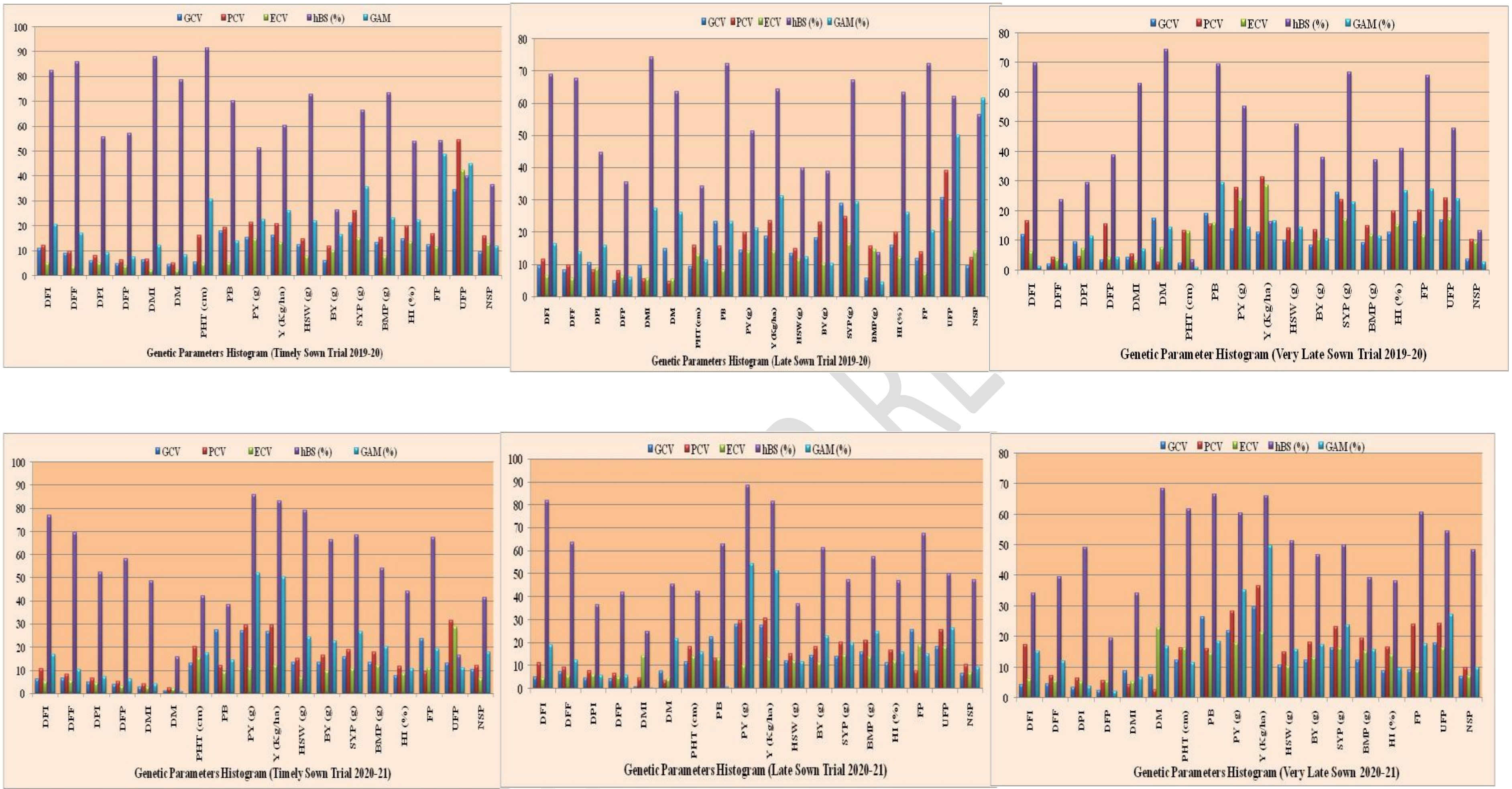


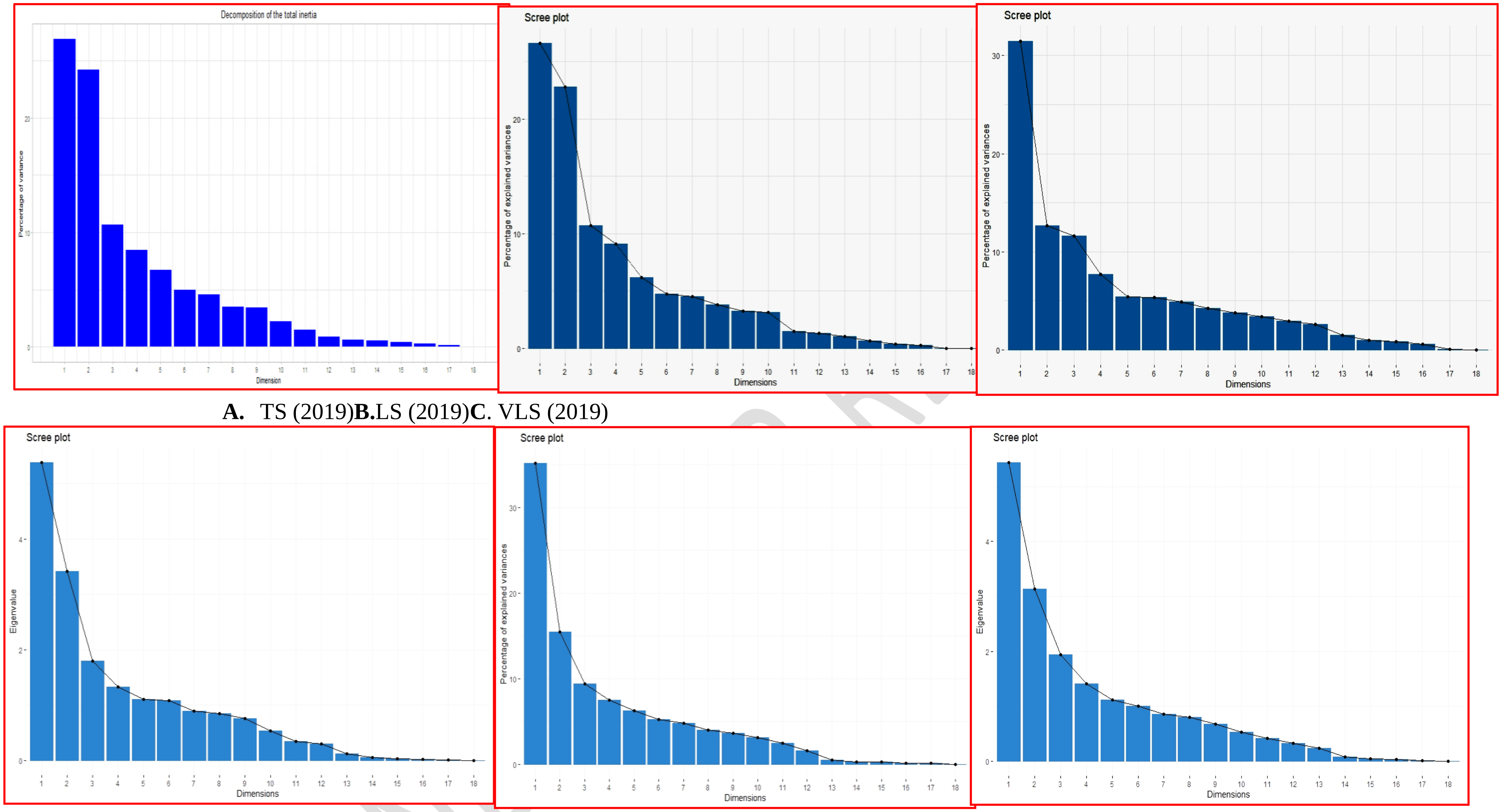
Figure no. 3 Genetic variability parameters Histogram for yield and yield attributing traits under TS, LS and VLS cropping environments during rabi 2019-20 and 2020-21.

Table 6: Pearson's correlation coefficients (r) for pooled data across environments (i.e., TS, LS & VLS) during rabi 2019-20 and 2020-21

Traits	Year	DFI	DFF	DPI	DFP	DMI	DM	PHT	PB	PY	Y	HSW	BY	SYP	BMP	HI	FP	UFP	NSP
DFI	**2019-20**	1																	
	2020-21	1																	
DFF	**2019-20**	**0.651****	1																
	2020-21	**0.861****	1																
DPI	**2019-20**	**0.816****	**0.946****	1															
	2020-21	**0.795****	**0.644****	1															
DFP	**2019-20**	**0.646****	**0.893****	**0.914****	1														
	2020-21	**0.674****	**0.707****	**0.944****	1														
DMI	**2019-20**	0.337	**0.675****	0.530**	**0.589****	1													
	2020-21	**0.517****	**0.668****	**0.661****	**0.843****	1													
DM	**2019-20**	0.384	0.519**	0.453*	**0.513****	**.877****	1												
	2020-21	0.480*	0.296	0.378	0.547**	**.715****	1												
PHT (cm)	**2019-20**	0.178	0.155	0.065	0.328	0.107	-.219**	1											
	2020-21	0.321	0.293	0.233	0.408*	0.028	0.097	1											
PB	**2019-20**	-0.187	**0.643****	-0.203	-0.029	0.123	0.095	**0.713****	1										
	2020-21	0.131	0.297	0.209	**0.612****	0.06	0.03	**.737****	1										
PY (g)	**2019-20**	-0.171	**0.750****	-0.27	-0.118	0.08	**0.787****	**0.537****	**0.583****	1									
	2020-21	0.147	0.117**	0.347	0.572**	0.167	**0.678****	**0.611****	**0.676****	1									
Y (Kg/ha)	**2019-20**	-0.231	**0.679****	-0.18	0.418*	0.202	**0.658****	**0.560****	**0.563****	**0.857****	1								
	2020-21	0.255	0.228**	0.354	0.493*	0.185	-0.093	0.445*	**0.856****	**0.964****	1								
HSW (g)	**2019-20**	-0.271	-0.131	-0.217	-0.14	-0.045	-0.101	0.586*	0.679**	0.544**	**0.642****	1							
	2020-21	0.223	0.141**	0.191*	0.158	0.083	-0.194*	0.422*	0.522*	0.412*	0.468*	1							
BY (g)	**2019-20**	0.056	**0.725****	-0.067	0.327	0.043	0.115	**0.713****	**0.962****	**0.517****	0.491*	0.463*	1						
	2020-21	-0.11	**0.578****	0.581**	-0.402*	-0.062	-0.074	0.582**	**0.678****	**0.856****	0.418*	0.645**	1						
SYP (g)	**2019-20**	0.532**	0.012	-0.07	0.33	0.519**	0.095	**0.600****	**0.780****	**0.628****	0.539**	0.587**	**0.691****	1					
	2020-21	0.136	0.189*	0.129	0.217	0.031	-0.024	**0.727****	**0.883****	0.504**	**0.717****	0.314**	**0.804****	1					
BMP (g)	**2019-20**	0.114	**-0.776****	0.073	0.452*	-0.021	0.066	**0.606****	0.501**	**0.553***	0.423*	**0.653****	**0.726****	0.536*	1				
	2020-21	-0.029	**0.914****	0.105	-0.027	0.069	-0.089	0.513**	0.457*	0.494*	0.400*	0.439*	**0.952****	**0.682****	1				
HI (%)	**2019-20**	-0.109	0.206	-0.126	-0.003	0.068	0.04	0.404*	0.433*	0.459*	0.493*	0.486*	0.510*	**0.678****	0.506*	1			
	2020-21	-0.204	-0.178*	-0.296	0.19	0.062	**0.893****	0.461*	**0.690****	**0.706****	0.411*	0.527*	**0.628****	**0.779****	0.424*	1			
FP	**2019-20**	-0.012	-0.035	-0.077	0.013	-0.019	-0.036	0.505*	0.479*	**0.657****	**0.704****	0.494*	**0.659****	**0.774****	0.599**	**0.747****	1		
	2020-21	-0.11	-0.067	-0.077	-0.145	-0.117	**-0.170**	0.493*	0.557*	**0.649****	**0.161**	0.409*	0.471*	**0.964****	0.456*	**0.716****	1		
UFP	**2019-20**	-0.182	-0.119	-0.136	-0.158	-0.059	-0.073	-0.314	-0.085	-0.098	-0.121	0.112	-0.265	-0.199*	-0.24	-0.078	0.163	1	
	2020-21	-0.086	-0.121	-0.12	-0.04	-0.136	-0.099	-0.163	-0.025	-0.153	-0.199	-0.088	-0.230	-0.106	-.259**	-0.164	0.170	1	
NSP	**2019-20**	-0.127	-0.103	-0.134	-0.046	-0.108	-0.092	-0.125	-0.173	-0.227	-0.213	-0.190	-0.137	0.456*	0.169	-0.241	0.064	0.062	1
	2020-21	-0.249	-0.212*	-0.145	-0.213*	-0.062	-0.106	-0.230**	-0.064	-0.312	-0.313	-0.019	-0.330	0.503*	0.072	-0.029	0.126	0.154	1

Table no. 7 Principal Component Analysis for major yield contributing variables under TS, LS and VLS trials during Rabi 2019-20 & 2020-21

Component	Eigenvalue						Percentage of variance						Cumulative % of variance					
	2019-20			2020-21			2019-20			2020-21			2019-20			2020-21		
	TS	LS	VLS	TS	LS	VLS	TS	LS	VLS	TS	LS	VLS	TS	LS	VLS	TS	LS	VLS
PC1	4.83	4.79	5.66	5.38	6.33	5.44	26.83	26.62	31.46	29.87	35.15	30.2	26.83	26.62	31.46	29.87	35.15	30.2
PC2	4.35	4.11	2.28	3.41	2.78	3.13	24.19	22.81	12.66	18.96	15.43	17.4	51.02	49.43	44.11	48.83	50.58	47.6
PC3	1.92	1.93	2.09	2.8	1.69	1.94	10.65	10.71	11.62	7.45	9.37	7.79	61.67	60.14	55.73	58.83	59.95	58.39
PC4	1.52	1.64	1.39	5.32	1.35	1.41	8.44	9.09	7.71	10.35	9.5	11.82	70.1	69.23	63.45	66.18	67.45	66.21
PC5	1.21	1.11	1.98	3.1	1.13	1.12	6.7	6.16	5.44	6.1	6.27	6.19	76.8	75.38	68.88	72.28	73.72	72.4
PC6	1.89	1.86	1.96	2.08	1.94	1.12	4.96	4.76	5.33	5.98	5.23	5.55	81.76	80.14	74.21	78.26	78.95	77.95
PC7	1.82	1.82	1.88	2.9	1.87	1.85	4.56	4.53	4.86	4.97	4.83	4.74	86.31	84.67	79.07	83.24	83.77	82.69
PC8	1.64	1.69	1.77	1.85	1.72	1.8	3.53	3.82	4.26	4.72	3.97	4.42	89.84	88.49	83.33	87.96	87.75	87.11
PC9	1.62	1.58	1.69	1.76	1.66	1.67	3.42	3.24	3.81	4.21	3.67	5.72	93.26	91.73	87.14	92.17	91.41	90.83
PC10	2.4	2.57	2.6	2.53	0.57	0.53	2.24	3.15	3.37	2.95	3.16	2.93	95.5	94.87	90.51	95.12	94.57	93.76
PC11	0.27	0.27	0.52	4.34	0.45	0.41	1.5	1.48	2.94	1.91	2.48	2.28	97	96.35	93.45	97.03	97.05	96.04
PC12	0.16	0.24	0.46	0.3	0.29	0.33	0.89	1.31	2.59	1.66	1.62	1.81	97.88	97.66	96.05	98.68	98.66	97.85
PC13	0.12	0.19	0.27	0.13	0.09	0.23	0.64	1.06	1.52	0.7	0.5	1.28	98.53	98.72	97.57	99.38	99.16	99.14
PC14	0.1	0.12	0.17	0.05	0.06	0.08	0.56	0.64	0.96	0.29	0.31	0.43	99.09	99.36	98.52	99.67	99.47	99.57
PC15	0.08	0.06	0.14	0.03	0.05	0.04	0.44	0.36	0.82	0.17	0.27	0.23	99.53	99.71	99.35	99.85	99.74	99.79
PC16	0.05	0.05	0.1	0.02	0.02	0.03	0.27	0.27	0.61	0.12	0.12	0.16	99.8	99.98	99.96	99.96	99.86	99.95
PC17	0.03	0	0.5	0.01	0.02	0.01	0.19	0.02	0.04	0.04	0.11	0.05	99.99	100	100	100	100	100
PC18	0	0	0	0	0.01	0	0.01	0	0	0	0.03	0	100	100	100	100	100	100



A. TS (2019)**B.**LS (2019)**C.** VLS (2019)

D.TS (2020)**E.**LS (2020)**F.**VLS (2020)

Figure no. 4 Graphical representation of Scree plot explaining variability of each principal component (A, B, C, D, E & F) of 113 diverse genotypes of chickpea (*Cicer arietinum*)

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