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Correlation and Path Analysis among Some Agro-Morphological Traits in Chickpea (*Cicer arietinum* L.) Genotypes under High and Low Temperatures of Sudan

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ABSTRACT

The objectives of this study were to assess the effect of temperature on seed yield and agro-morphological traits as well as correlation and path analysis in 48 chickpea genotypes grown under normal and late sowing conditions in two locations (Merowe and Gezira) during 2018/ 19. The forty eight genotypes comprised released varieties as checks and lines from ICARDA. The study was carried out in alpha lattice design with three replications. Analysis of variance showed that differences among genotypes, sowing dates, locations and their first order interaction were highly significant ($P \leq 0.01$) for the most studied traits. Under both environments, the correlation studies revealed that seed yield was positively and highly significantly correlated with 100 – seed weight, biomass, harvest index and seed yield per plant. The path analysis confirmed that the biomass followed by harvest index, seed yield per plant, 100 - seed weight, seed yield per plant, number of seeds per pod and number of pods per plant had the maximum positive direct influence on seed yield under heat stress and non- heat stress conditions. It was concluded that biomass, harvest index, 100 – seed weight and seed yield per plant can be good selection criteria for improving seed yield in chickpea under heat stress and non - heat stress conditions in Gezira and Northern states of Sudan.

***Key words**:* Chickpea, correlation, heat stress, late sowing, path analysis, seed yield, traits.

تحليل الارتباط ومعامل المسار لبعض الصفات الزراعية - المورفولوجية لطرز وراثية من الحمص تحت درجات الحرارة العالية والمنخفضة في ولايتي الجزيرة والشمالية

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المستخلص

الهدف من هذه الدراسة هو تقييم تأثير درجة الحرارة على محصول الحبوب والارتباط ومعامل المسار لمحصول الحبوب والصفات المورفولوجية الزراعية لعدد 48 سلاله من الحمص تحت ظروف الزراعة العادية والمتأخرة. تتألف الطرز الوراثية الثمانية والأربعون من أصناف مجازة بالإضافة الى سلالات تم استجلابها من إيكاردا. تم تقييم الطرز الوراثية تحت ظروف الزراعة العادية والمتأخرة في موقعين (مروي والجزيرة) خلال فصل الشتاء موسم 2018/ 19. نفذت الدراسة بتصميم ألفا بثلاثة مكررات. أظهر تحليل التباين (ANOVA) وجود فروق معنوية عالية بين السلالات وتواريخ الزراعه والمواقع والتداخل بينهما لمعظم الصفات المدروسة. في كلا البيئتين أوضحت دراسات الارتباط أن انتاج الحبوب كان مرتبطا موجبا ومعنويا مع وزن 100 حبة، الكتلة الحيوية، معامل الحصاد وحاصل البذور للنبات. أكد تحليل المسار أن الكتلة الحيوية متبوعة بمعامل الحصاد، وحاصل البذور للنبات، ووزن 100 حبه، وعدد الحبوب في القرن، وعدد القرون في النبات كان لها أقصى تأثير مباشر وإيجابي على انتاج الحبوب تحت ظروف الإجهاد الحراري وغير الإجهاد الحراري. لذلك يشير هذا البحث إلى أن الكتلة الحيوية ، ومعامل الحصاد، ووزن 100 حبه وحاصل البذور للنبات يمكن أن تكون معايير اختيار جيدة لتحسين انتاج الحبوب في الحمص تحت ظروف الإجهاد الحراري وغير الاجهاد الحراري في ولايتى الجزيرة والشمالية.

كلمات المفتاحية : الحمص، الإجهاد الحراري، الزراعة ألمتأخرة الارتباط، تحليل المسار ، الصفات، انتاج الحبوب.

Introduction

Chickpea (*Cicer arietinum L.*) has been the second most important edible legume plant grown worldwide. It has an important role in meeting the protein needs of people in undeveloped countries, especially where the income imbalance is experienced (Bozoglu and Ozcelik, 2005). In Sudan, chickpea is an important cash crop which faces strong competition with the other winter legumes, mainly faba bean, in its traditional area of production in Northern Sudan. Chickpea is also grown successfully in Hawata area in eastern Sudan and Jebel Marra in western Sudan (Faki *et al.*, 1992; Sheikh Mohamed, 1991). In recent years, chickpea area has increased steadily in central Sudan, especially in the Gezira scheme and in New Halfa (Eastern Sudan). The growing season is restricted to a short period of time by the high temperatures prevailing at the beginning and at the end of the season (Amel *et al.*, 2015). The chickpea yields in Sudan vary from 0.83 to

2.8 t/ha, depending on weather conditions (Ahmed, 1996). Temperature is one of the most constraints in the main chickpea production areas in Sudan.

Chickpea productivity is constrained by several biotic and abiotic stresses (Gaur *et al.*, 2008) and temperature is one of the most important determinants of crop growth over a range of environments (Summerfield *et al.*, 1990) and may limit chickpea yield (Basu *et al.*, 2009).

Chickpea reproductive stages (flowering and podding) are vulnerable to external environmental changes and heat stress (Krishnamurthy *et al.*, 2011). Frequent decreases in the yields of chickpea seed were observed when plants were exposed to high temperatures (> 350C) at flowering and pod development stages (Wang *et al.*, 2006).

Yaqoob *et al.* (1990), studied correlation among 6 yield components in 12 genotypes of chickpea, reported that correlation between seed yield and days to maturity was negative. Eser *et al.*, (1991) recorded strong associations between seed yield per unit area and harvest index, 100 - seed weight and seed per plant in chickpea. Jahhar and Mane (1991) reported that the correlation was significant between chickpea seed yield and all yield studied parameters, except plant height.

Ciftci *et al.*, (2004) stated that positive and significant correlations were found among seed yield and plant height, number of branch, number of pods per plant, harvest index and number of seeds per plant. Ozveren *et al.* (2006) reported that, seed yield per plant was positively and significantly correlated with plant height, first pod height, total pod number, full pod number, and seed number and improving these traits may leads increase seed yield per plant.

Singh *et al.* (1990) reported that correlation and path coefficient analysis showed that biological yield and harvest index were the major direct contributors to seed yield.

To date, limited genetic resources for heat stress tolerance in chickpea have been reported (Devasirvatham *et al.*, 2013; Jha *et al.*, 2015). Heat tolerant varieties/cultivars are needed for improving chickpea yields in warm season environments and late sowing conditions especially in central Sudan (Gezira State), to expand its cultivation to new areas and improving its resilience to the impacts of climate change. The genetic variability present in the base population for desired characters plays an important role in developing improved chickpea genotypes. Less information is available on chickpea genotypes tolerant to heat stress under Sudan conditions. Hence the objectives of this study were to assess the correlation and path analysis of yield and agro-morphological traits among the chickpea genotypes under non – heat stress and heat stress conditions.

Materials and Methods

Description of the study areas

Two experiments were carried out for consecutive winter season 2018 and 2019 at two locations in Gezira Research Station Farm (GRSF) of the Agricultural Research Corporation (ARC), Wad Medani, Sudan. Gezira Research Station Farm is located in the central clay plain of the Sudan at latitude of 14° 24' N, longitude of 33° 29' E and elevation of 407 meters above sea level. The soil of the Gezira Research Farm is heavy, alkaline, cracking clay (clay 58%, pH 8.3, organic matter 0.02, nitrogen 0.25, phosphorus 0.06 and potash 3.0%). The other location at farmers' field in the Northern state of Sudan, Merowe locality (latitude: 18° 27' 0" N, longitude: 31° 49' 59" E, elevation: 258 meters).

Plant materials

Forty three chickpea genotypes were selected from advanced materials of the national chickpea breeding program. In addition, five improved released chickpea cultivars namely (Shiekh Mohamed, Merowe, Wad Hamid, Salwa and *Hwata*) were included as checks (Table 1).

Table (1). Accession No. and Origin of 48 Chickpea Genotypes Used in the Study

No	Accession No.	Origin		No	Accession No.	Origin
1	FLIP 09 – 181 C	ICARDA		**30**	22204	ICARDA
2	LIP 09 – 179 C	ICARDA		**31**	22272	ICARDA
3	FLIP 09 – 184 C	ICARDA		**32**	222389	ICARDA
4	FLIP09 – 155 C	ICARDA		**33**	222303	ICARDA
5	FLIP09 – 438 C	ICARDA		**34**	222242	ICARDA
6	FLIP09 – 261 C	ICARDA		**35**	22373	ICARDA
7	FLIP 07 – 236 C	ICARDA		**36**	22206	ICARDA
8	FLIP 09 – 259 C	ICARDA		**37**	22384	ICARDA
9	FLIP08 – 86 C	ICARDA		**38**	22341	ICARDA
10	FLIP09 – 6 C	ICARDA		39	22302	ICARDA
11	FLIP 08-59 C	ICARDA		40	22260	ICARDA
12	FLIP 09-182 C	ICARDA		41	22266	ICARDA
13	FLIP 09-187 C	ICARDA		42	22392	ICARDA
14	FLIP09 – 240 C	ICARDA		43	22261	ICARDA
15	22330	ICARDA		44	Shiekh Mohamed	Released commercial cultivar
16	22304	ICARDA		45	Merowe	Released commercial cultivar
17	22317	ICARDA		46	Wad Hamid	Released commercial cultivar
18	22233	ICARDA		47	Salwa	Released commercial cultivar
19	22278	ICARDA		48	Hwata	Released commercial cultivar
20	22267	ICARDA				
21	22232	ICARDA				
22	22223	ICARDA				

23	22235	ICARDA				
24	22366	ICARDA				
25	22293	ICARDA				
26	22380	ICARDA				
27	22362	ICARDA				
28	22254	ICARDA				
29	22335	ICARDA				

Experimental Design and Field Managements

In each location, the experiments were arranged in 12 x 4 alpha lattice design (incomplete design) with three replications. Each replicate consisted of twelve incomplete blocks and four plots in each block. The field was prepared in disc ploughed, disc harrowed, leveled then ridged (60 cm). Each genotype was sown in a separate plot which consisted of one ridge; each ridge was 4 m long. Seeds were sown in holes along the top of the ridge at a rate of two seeds per hole 0.1 m apart. Temperature stress was induced by manipulation of the sowing dates, normal and late (second week of November and first week of December, respectively) were used during both seasons. The experiments were irrigated every 12 to 14 days to avoid any water stress. The crop took a total of 11 irrigations during the growing period. A starter dose of nitrogen in the form of urea was applied at a rate of 43 kg N/ha with the third irrigation. The experiments were kept weed-free by hand weeding twice at early stages of crop cycle. Seed yield was assessed from a net area of 2.4 m2. Monthly maximum, minimum and mean temperatures during the cropping season 2018/19 for the two locations obtained from the Karima and Gezira metrological stations (Fig.1 and 2).

Measurements of growth and yield parameters

In two locations, the data of phonological and agronomical traits were collected during the growth period of the crop. In each plot, five individual plants were randomly selected for most of traits, and values for each trait were calculated as an average. The data were recorded on days to 50% flowering, days to 90% physiological maturity, plant height (cm), number of pods per plant, number of seeds per plant, number of seeds per pod, 100 - seed weight (g), seed yield per plant (g) and biomass (t ha^{-1}). The harvest index (%) was calculated as (seed yield / total shoot dry weight) x 100. Seed yield (t ha^{-1}) was determine by harvested the four meter length in each plot for yield. Weighed using electronic balance and then seed yield per plot was converted to seed yield in (t ha^{-1}).

Statistical analysis

The data were subjected to combined analysis of variance using the GenStat 12th edition statistical analysis package for windows (2009) to test the level of significance among the genotypes for different traits under study. Under normal and late sowing conditions simple correlation coefficients among all traits were calculated based on the overall means of genotypes. The correlation coefficients were estimated according to the formulae given by Al-Jibouri *et al.*, (1958). Path analysis to estimate the direct and indirect contributions of some traits to seed yield (t ha^{-1}) was also conducted using the method described by Dewey and Lu (1959).

Results and Discussion

Combined analysis of variance

The combined analysis of variance for studied traits under normal sown (non- heat stress) and late sown (heat stress) were presented in Table 2. Combined analysis of variance showed highly significant difference ($P \leq 0.001$) among genotypes, locations, and sowing dates and their interactions for the most studied traits. This variation can be exploited for selection of heat tolerant chickpea genotypes. These results were similar to Jeena *et al.* (2005) who reported high amount of genetic variation for number of pods per plant, 100-seed weight and seed yield. The interaction between the genotypes and locations were not significant for days to 50% flowering indicating that the performance of the genotypes with respect to this trait was consistent across locations.

Seed yield performance

The mean seed yield of early sowing (non – heat stress) was about two times greater than that of late sowing (heat stress). Under non – heat stress, entry no. 1 (FLIP 09 – 181 C) out - yielded all genotypes, in particular, the four checks cultivars (Wad Hamid, Shiekh Mohamed, Salwa and Hwata) by about 34.3, 23.1, 10.6 and 10.1%, respectively (Table 3). The results also, showed that under heat stress, entry no. 11 out - yielded the five chickpea commercial cultivars Merowe, Shiekh Mohamed, Hwata, Wad Hamid and Salwa by 30.1, 17.4, 9.5, 6.7 and 4.7%, respectively. Based on seed yield under the heat stress the entries no. 11, 4, 30, 34 and 43 were relatively more adapted to heat and exceeded cultivar Merowe in seed yield (Table 3). Seed yield was reduced at the late sowing date (heat stress) which may be reasonably explained by the relatively high temperatures prevailing during fertilization and pod setting stage.

Correlation coefficient analysis

Normal sowing (non- heat stress)

Under non – heat stress conditions, simple correlation coefficients were calculated based on means averaged over the two locations (Table 4). The character 100 - seed weight recorded positive and highly significant correlation with seed yield (r = 0.4119**). This result is in agreement with that of Shara (2019). The highest positive relationship was observed between seed yield and harvest index (r = 0.4214**). This result was in agreement with those of Erman *et al.*, (1997) and Ciftci *et al.*, (2004). Seed yield showed highly positive significant correlation with plant height (r = 0.3107*) and biomass yield (r = 0.3565*), while days to 50% flowering (-0.4127**) and days to 90% maturity (-0.3401*) demonstrated highly negative significant correlation with seed yield. These results agreed with those of many workers (i.e. Amare *et al.*, 2020; Fatih and Amel, 2018).

Highly significantly positive association was consistently observed between days to 50 % flowering and days to 90% maturity indicating that early flowering may lead to early maturity. These results are in agreement with those of Dasgupta *et al.* (1992).

Plant height exhibited positive and highly significant correlation with the 100 – seed weight, seed yield per plant, but it was correlated negatively and significantly with days to 50% flowering, number of seeds per plant and number of seeds per pod (Table 4).

The number of seeds per pod recorded positi ve and highly significant correlation with days to 50% flowering, number of seeds per plant and harvest index but it was correlated negatively with plant height, number of seeds per plant and 100 - seed weight.

The biomass showed significantly positive correlation with the seed yield t ha1, seed yield per plant and negative correlation with other characters. The number of pods per plant has positive and non-significant correlation with days to 50% flowering, days to 90% maturity, number of seeds per pod, biomass and seed yield t ha-1, but it has negative and highly significant correlation with 100 – seed weight (Table 4).

The seed yield per plant was positively and significantly correlated with plant height, number of pods per plant, 100 – seed weight and seed yield t ha1, but it has significant negative correlation with days to 90% maturity. These results agreed with the findings reported by Muhammd *et al.*, (2002).

Harvest index has positive and significant correlation with number of seeds per pod, 100 – seed weight, seed yield per plant and seed yield t ha1. On the other hand, it has negative but non-significant correlation with number of pods per plant, number of seeds per plant and biomass (Table 4).

100 -seed weight had a highly significant negative correlation with the number of pod per plant, number of seeds per pod and number of seeds per plant. This negative correlation indicates a compensatory relationship between them. These results are in close conformity to the findings of Banik *et al.* (2017) and Shafique *et al.* (2016).

Seed yield per plant exhibited significant and positive correlation with biomass, number of pods per plant, harvest index and 100 -seed weight. These results were in conformity with those of Vaghela *et al.* (2009).

Late sowing (heat stress)

Under late sowing (heat stress conditions), the simple correlation coefficients were determined between characters investigated based on mean values averaged over of the two locations (Table 5). Such, correlations help breeders to identify the characters that could be used as selection criteria in breeding program. The results indicate that seed yield t ha^{1} is positively and highly significantly correlated with biomass, seed yield per plant, harvest index, number of pods per plant and 100 – seed weight (r = 0.7498***, r = 0.7021***, r = 0.6793***, r = 0.6729*** and r = 0.2856*, respectively). The high positive correlation coefficient indicates that selection based on biomass, seed yield per plant, number of pods per plant, harvest index and 100 – seed weigh have an equal contribution towards increasing the seed yield in chickpea under heat stress condition. These results are in close agreement with those reported by Tesfamichael *et al.* (2015).

The 100 – seed weight was positively and significantly correlated with seed yield t ha^{1}. This result was comparable to that obtained by Khan *et al.* (1989). On the other hand, there was negative and significant correlation between seed yield t ha^{1} and days to 50% flowering (Table 5). This result is in agreement with the results of Singh *et al.* (2001) and Singh *et al.* (2017) who reported significant negative association between seed yield and days to 50% flowering.

Number of pods per plant has positive highly significant correlation with number of seeds per plant (r = 0.9396***), seed yield per plant (r = 0.7703***), harvest index (r = 0.5463***) and biomass (r = 0.3753**). Days to 50% flowering showed considerable negative and significant correlation with all the traits studied except days to 90% maturity. Number of seeds per plant had positive and significant correlation with number of pods per plant, seed yield per plant, harvest index and biomass, while it was negatively correlated with days to 50% flowering, days to 90% maturity and plant height. There was a negative correlation observed between harvest index and days to 50% flowering, days to 90% maturity, plant height and number of seeds per pod. There was a positive and significant correlation observed between seed yield per plant and number of pods per plant, number of seeds per plant and 100 – seed weight (Table 5). 100 –seed weight was negatively correlated with all traits except plant height and seed yield per plant. Biomass had a positive correlation with days to 90% maturity, plant height, number of pods per plant, number of seeds per pod, harvest index and 100 – seed weight.

Plant height showed positive and highly significant correlation with 100 - seed weight and seed yield per plant, while it was negatively correlated with number of pods per plant. Similar findings have been reported by Tejashwini *et al.* (2018).

Path coefficient analysis

Normal sowing (non- heat stress*)*

Table 6 shows path coefficient analysis under non– heat stress for eleven characters in chickpea based on data combined over two locations. Path coefficient analysis using seed yield as dependent variable and days to 50% flowering, days to 90% maturity, plant height, number of pods per plant, number of seeds per plant, number of seeds per pod, 100 - seed weight, seed yield per plant, biomass and harvest index as independent variables. Path coefficient analysis showed that among the ten traits; 100 – seed weight (p.c = 0.7902) followed by number of pods per plant (p.c= 0.5150), number of seeds per pod (p.c = 0.4652), harvest index (p.c = 0.2906) and biomass (p.c = 0.21359) had high positive direct influence on seed yield. This result was comparable to that obtained by Usman *et al.* (2012) and Jivani *et al.* (2013). 100 – seed weight had the greatest direct effect on seed yield (p.c= 0.7902), its indirect effect on seed yield was more positive through number of pods per plant but negative and low through days to 50% flowering, days to 90% maturity and number of seeds per pod.

The path coefficient analysis revealed that number of seeds per plant (p.c = -0.9080) had maximum negative direct effect on seed yield. The indirect effects of days to 50% flowering due to, days to 90% maturity, number of pods per plant, number of seeds per plant and number of seeds per pod were positive, but due to other characters were negative (Table 6).

The results of correlation and path analysis indicated that 100 – seed weight, harvest index, seed yield per plant and biomass were the major yield contributing characters as they showed positively and highly significant correlation with seed yield and also had highly positive direct effects. Thus these four characters could be considered as the most important for selection in order to improve the seed yield in chickpea under non – heat stress conditions. In addition number of seeds per plant also affected seed yield indirectly through number of pods per plant.

Late sowing (heat stress)

The direct and indirect effects of different characters on seed yield under heat stress condition are presented in Table 7. Path coefficients were computed to estimate the contribution of individual characters to seed yield. According to the path coefficient analysis the harvest index (0.5183), biomass (0.4545), number of seeds per plant (0.1478), seed yield per plant (0.1285), days to 90% maturity (0.0964), plant height (0.0673), number of pods per plant (0.0560), number of seeds per pod (0.0410) and 100 – seed weight (0.0343) had positive direct influence on seed yield (Table 7). The harvest index recorded highest positive direct effects on seed yield. The main reason for significant effect of harvest index was due to the close positive correlation of this character with seed yield (0.6793***). These results indicated that selection for this character may be effective in the improvement of chickpea seed yield under heat stress condition. The earlier studies for direct effect on seed yield for harvest index and biological yield were reported by Kuldeep *et al.* (2014) and Tadesse *et al.* (2016). Also these results confirmed those of Agrawal *et al.* (2018). Other trait such as days to 50% flowering (-0.1271) had negative direct effect on seed yield. This is in agreement with the findings of Vartika *et al*. (2017) and Fatih and Amel (2018).

The indirect effects of plant height due to, 100 – seed weight, seed yield per plant and biomass were positive, but those due to days to 50% flowering, days to 90% maturity, number of pods per plant, number of seeds per plant, number of seeds per pod and harvest index were negative. Also the indirect effects of 100 – seed weight due to all traits were positive except those due to days to 50% flowering, days to 90% maturity and number of seeds per pod which were negative (Table 7). In addition number of pods per plant also affected seed yield indirectly through harvest index. The estimated residual effect of path analysis was very low (0.07592), indicating that about 99% of the variability in seed yield was contributed by the traits studied.

Conclusion

The study revealed the existence of significant genetic variability among the tested genotypes for the different traits. The presence of significant genetic variability among genotypes suggests the possibility of improving traits through direct and indirect selection.

The genotypes no. 1, 40. 3, 6, 39 and 43 recorded the best average seed yield under non- heat stress and out-yielded the check, Salwa by 10.6, 10.6, 7.1. 3.5, 2.2 and 1.9%, respectively. On the other hand, under heat stress, the genotype no. 11 gave the highest seed yield outperforming the five checks Merowe, Shiekh Mohamed, Hwata, Wad Hamid and Salwa by 30.1%, 17.4%, 9.5%, 6.7% and 4.7%, respectively.

Under heat stress and non – heat stress conditions the negative correlations of the characters days to 50% flowing and days to 90% maturing with seed yield, indicate that the late maturing genotypes generally performed better than early maturing genotypes.

Seed yield (t ha-1) was positively and highly significantly correlated with seed yield per plant, harvest index, 100 – seed weight and biomass (t ha-1). These four traits could be used as potential selection criteria in breeding programs for developing high yielding chickpea genotypes under heat stress and non – heat stress conditions.

Path coefficient analysis showed that among the ten causal (independent) traits; the harvest index, biomass (t ha-1), number of seeds per plant and seed yield per plant had highly positive direct effects on seed yield. Thus, these traits can be used as criteria in selection for the improvement of seed yield in chickpea under late sown (heat stress) condition.

Table (2). Mean squares of seed yield (t ha-1), vegetative traits and some yield components of 48 chickpea genotypes grown under normal sown (non- heat stress) and late sown (heat stress) and two locations (Gezira and Merowe) during winter season 2018/ 19.

Traits	Genotype (d.f = 47)	Sowing date (d.f = 1)	Location (d.f = 1)	Geno. x Sowing date (d.f = 47)	Geno. x Location (d.f = 47)	Geno. x Sowing date x Location (d.f = 47)
Days to flowering	28453.47***	205.44*	552.25***	2596.72**	2006.25n.s	2294.25*
Days to maturity	9020.57***	4505.77***	30990.67***	2114.65n.s	6947.41***	2023.11n.s
Plant height (cm)	10046.56***	9702.25***	12904.96***	2344.96*	2634.07**	1797.08n.s
No. of pods / plant	104719.0***	192512.5***	237806.6***	56051.6***	78148.5***	59265.7***
No. of seeds / plant	189515.9***	221754.7***	436623.6***	91055.7***	114613.4***	77633.1***
No. of seeds / pod	9.84340***	0.70350***	3.65606***	1.75131n.s	1.95541*	0.86995n.s
100-seed weight (g)	23581.26***	592.11***	2525.06***	593.51n.s	1349.02***	845.32n.s
Seed yield / plant (g)	14797.99***	16838.31***	56792.85***	4999.95***	9292.77***	5853.38***
Harvest index (%)	6390.01***	8406.60***	6789.07***	3674.45***	5358.85***	3707.94***
Biomass (t ha^{-1})	646292537***	777473307***	492209298***	181320100*	442390185***	280082879***
seed yield (t ha^{-1})	101288763***	299575518***	40955733***	37786491n.s	47252430*	31099675n.s

* , ** and *** Significant at the P = 0.05, p = 0.01 and P = 0.001, respectively.
n.s = non - significant.

Table (3). Seed yield (t ha-1) of 48 chickpea genotypes grown under normal sown (non- heat stress) and late sown (heat stress), averaged over two locations.

No.	Normal	Late	No.	Normal	Late	No.	Normal	Late
1	3.93	1.52	**18**	3.00	1.50	**35**	2.74	1.44
2	2.61	1.36	**19**	3.45	1.70	**36**	2.20	1.61
3	3.78	1.32	**20**	2.18	1.12	**37**	2.03	0.89
4	3.45	2.12	**21**	3.16	1.42	**38**	3.26	1.16
5	3.21	1.75	**22**	2.55	1.47	**39**	3.59	1.56
6	3.64	1.30	**23**	3.04	1.12	**40**	3.93	1.31
7	2.74	1.37	**24**	2.88	1.14	**41**	1.84	0.93
8	2.72	1.05	**25**	2.90	1.44	**42**	1.91	1.07
9	2.82	1.05	**26**	2.73	1.86	**43**	3.58	1.99
10	3.45	1.42	**27**	3.40	1.69	**44**	3.02	2.08
11	3.29	2.52	**28**	2.09	0.83	**45**	3.91	1.76
12	2.58	1.74	**29**	2.94	1.50	**46**	2.58	2.35
13	3.20	1.77	**30**	3.14	1.91	**47**	3.51	2.40
14	3.51	1.61	**31**	2.40	1.51	**48**	3.53	2.28
15	2.83	1.29	**32**	2.87	1.10	**Mean**	2963	1521
16	2.84	1.63	**33**	1.86	0.98	**S.E ±**	1009	490.7
17	2.20	1.09	**34**	3.22	1.94	**C.V (%)**	34.0	32.3

Table (4). Simple correlation coefficient among seed yield, yield components and some vegetative traits of chickpea genotypes grown under normal sown (non- heat stress) conditions based on means averaged over two locations.

Traits	DF	DM	PH	NPP	NSPL	NSP	100-S.W	SYP	HI (%)	BIO
DM	0.7978***									
PH	-0.3159*	-0.1950n.s								
NPP	0.0683n.s	0.1496n.s	-0.1634n.s							
NSPL	0.1701n.s	0.1895n.s	-0.2813*	0.8535***						
NSP	0.2894*	0.1888n.s	-0.3610*	0.2103n.s	0.6194***					
100-S.W	-0.4506**	-0.4116**	0.5583***	-0.5275***	-0.7153***	-0.6040***				
SYP	-0.4710***	-0.3924**	0.2792*	0.3889**	0.2146n.s	-0.1719n.s	0.3714**			
HI (%)	-0.4053**	-0.2879*	0.0504n.s	-0.0390n.s	-0.1967n.s	0.2767*	0.3162*	0.2836*		
BIO	-0.2182n.s	-0.1981n.s	0.2412n.s	0.2595n.s	0.1680n.s	-0.0749n.s	0.1233n.s	0.3150*	-0.2259n.s	
SY (t ha^{-1})	-0.4127**	-0.3401*	0.3107*	0.2457n.s	0.0494n.s	-0.1652n.s	0.4119**	0.8100***	0.4214**	0.3565*

DF: Days to 50 % flowering, DM: Days to 90 % maturity, PH: Plant height (cm), NPP Number of pods per plant, NSPL: Number of seeds per plant, NSP: Number of seeds per pod, 100-S.W: Hundred seed weight (g), SYP: seed yield per plant (g), HI: Harvest index (%), BIO: Biomass (t ha-1) and SY: Seed yield (t ha-1).

Table (5). Simple correlation coefficient among seed yield, yield components and some vegetative traits of chickpea genotypes grown under late sown (heat stress) conditions based on means averaged over two locations.

Traits	DF	DM	PH	NPP	NSPL	NSP	100-S.W	SYP	HI (%)	BIO
DM	0.7116***									
PH	-0.2143n.s	-0.1029n.s								
NPP	-0.3832**	-0.4919***	-0.0758n.s							
NSPL	-0.2841*	-0.3651*	-0.2255n.s	0.9396***						
NSP	0.2190n.s	0.2667n.s	-0.3759**	-0.0022n.s	0.3081*					
100-S.W	-0.3770**	-0.3168*	0.4379**	-0.0027n.s	-0.2582n.s	-0.7124***				
SYP	-0.6089***	-0.5793***	0.2116n.s	0.7703***	0.6154***	-0.3063*	0.5091***			
HI (%)	-0.5000***	-0.4116**	-0.0834n.s	0.5463***	0.4909***	-0.0882n.s	0.1928n.s	0.4997***		
BIO	-0.3222*	-0.2278n.s	0.3753**	0.3753**	0.2966*	-0.0749n.s	0.1341n.s	0.4031**	0.1585n.s	
SY (t ha^{-1})	-0.6099***	-0.4547**	0.2309n.s	0.6729***	0.5745***	-0.1346	0.2856*	0.7021***	0.6793***	0.7498***

DF: Days to 50 % flowering, DM: Days to 90 % maturity, PH: Plant height (cm), NPP Number of pods per plant, NSPL: Number of seeds per plant, NSP: Number of seeds per pod, 100-S.W: Hundred seed weight (g), SYP: seed yield per plant (g), HI: Harvest index (%), BIO: Biomass (t ha-1) and SY: Seed yield (t ha-1).

Table (6). Path coefficient analysis showing direct and indirect effects of different traits on seed yield (t ha-1) of 48 chickpea genotypes grown under normal sown (non- heat stress) conditions based on means averaged over two locations.

Traits	Indirect effect										Direct effect
	DF	DM	PH	NPP	NSPL	NSP	100-S.W	SYP	HI (%)	BIO	Seed yield (t ha^{-1})
DF	___	-0.0041	-0.0295	0.0391	-0.1564	0.1317	-0.3633	0.0516	-0.1118	-0.0534	0.0824
DM	0.0653	___	-0.0175	0.0702	-0.1662	0.0927	-0.3009	0.0455	-0.0828	-0.0469	0.0051
PH	-0.0257	0.0010	___	-0.0892	0.2601	-0.1461	0.2020	-0.0608	0.0097	0.0556	0.0946
NPP	0.0063	-0.0007	-0.0164	___	-0.7756	0.0905	0.3128	0.0599	-0.0073	0.0608	0.5150
NSPL	0.0142	-0.0009	-0.0271	0.4399	___	0.2852	0.1800	0.0809	-0.0534	0.0398	-0.9080
NSP	0.0233	-0.0010	-0.0297	0.1002	-0.9080	___	-0.1490	0.0667	-0.0863	-0.0170	0.4652
100-S.W	-0.0379	0.0020	0.0223	0.1328	-0.2068	-0.0877	___	-0.0401	0.0816	0.0731	0.7902
SYP	-0.0379	0.0021	0.0512	0.1002	-0.5567	-0.2763	0.2821	___	0.0875	0.0286	0.1123
HI (%)	-0.0317	0.0015	0.0032	-0.0130	0.1669	-0.1381	0.2220	-0.0338	___	-0.0500	0.2906
BIO	-0.0187	0.0010	0.0223	0.1328	0.6545	-0.0335	0.2450	-0.0136	-0.0616	___	0.2359

DF: Days to 50 % flowering, DM: Days to 90 % maturity, PH: Plant height (cm), NPP Number of pods per plant, NSPL: Number of seeds per plant, NSP: Number of seeds per pod, 100-S.W: Hundred seed weight (g), SYP: seed yield per plant (g), HI: Harvest index (%), BIO: Biomass (t ha-1).

Table (7). Path coefficient matrix showing direct and indirect effects among seed yield (t ha-1) and related traits of 48 chickpea genotypes grown under late sown (heat stress) conditions based on means averaged over two locations.

Traits	Indirect effect										Direct effect
	DF	DM	PH	NPP	NSPL	NSP	100-S.W	SYP	HI (%)	BIO	Seed yield (t ha^{-1})
DF	___	0.0678	-0.0143	-0.0210	-0.0409	0.0084	-0.0209	-0.0483	-0.2648	-0.1432	-0.1271
DM	-0.0894	___	-0.0069	-0.0272	-0.0534	0.0095	-0.0197	-0.0401	-0.2230	-0.1020	0.0964
PH	0.0270	-0.0099	___	-0.0045	-0.0348	-0.0153	0.0072	0.0558	-0.0481	0.1796	0.0673
NPP	0.0478	-0.0469	-0.0054	___	0.1391	0.0014	0.0263	-0.0008	0.2858	0.1702	0.0560
NSPL	0.0352	-0.0348	-0.0158	0.0526	___	0.0136	0.0210	-0.0331	0.2558	0.1328	0.1478
NSP	-0.0260	0.0224	-0.0251	0.0019	0.0493	___	-0.0098	-0.0938	-0.0595	-0.0358	0.0410
100-S.W	0.0778	-0.0554	0.0141	0.0429	0.0908	-0.0117	___	0.0649	0.2634	0.1812	0.0343
SYP	0.0478	-0.0301	0.0292	-0.0003	-0.0381	-0.0299	0.0173	___	0.0951	0.0569	0.1285
HI (%)	0.0649	-0.0414	-0.0062	0.0308	0.0729	-0.0047	0.0174	0.0235	___	0.0781	0.5183
BIO	0.0400	-0.0216	0.0265	0.0209	0.0432	-0.0032	0.0136	0.0161	0.0890	___	0.4545

DF: Days to 50 % flowering, DM: Days to 90 % maturity, PH: Plant height (cm), NPP Number of pods per plant, NSPL: Number of seeds per plant, NSP: Number of seeds per pod, 100-S.W: Hundred seed weight (g), SYP: seed yield per plant (g), HI: Harvest index (%), BIO: Biomass (t ha-1).

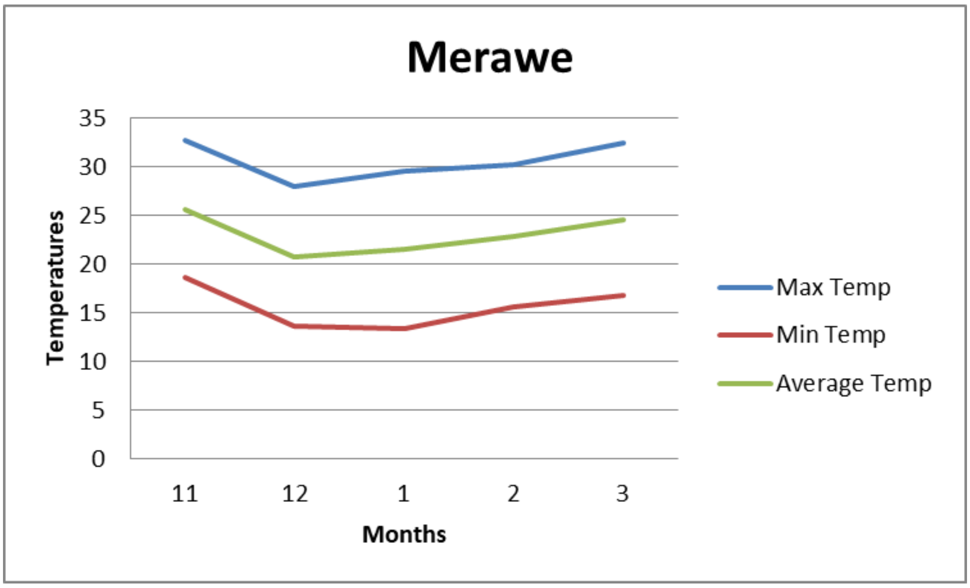

Fig.(1): Metrological data for minimum, maximum and mean air temperature (°C) Merawe location during winter season 2018/ 19. (Source: Karima Metrological Station.**)**

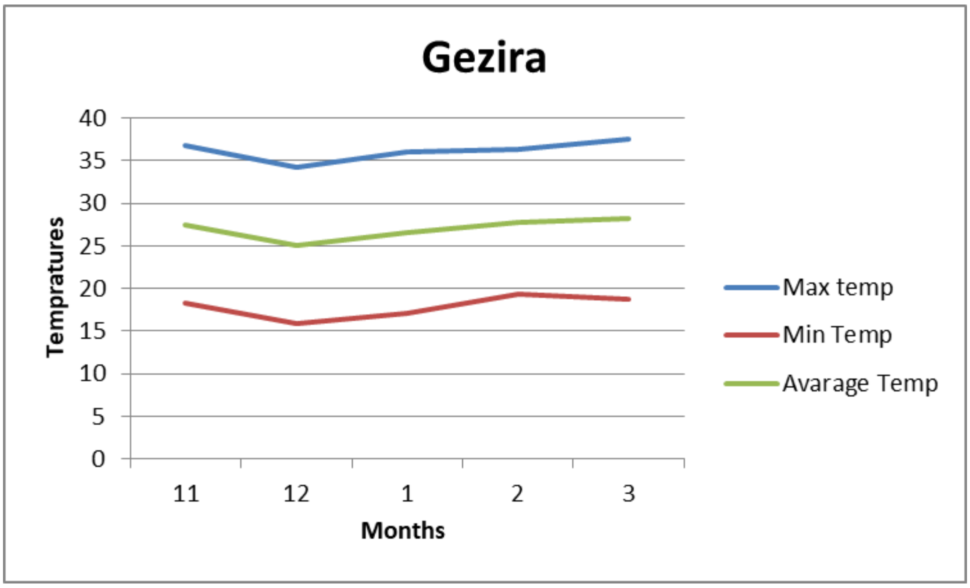

Fig.(2): Metrological data for minimum, maximum and mean air temperature (°C) Gezira location during winter season 2018/ 19. (Source: Gezira Metrological Station.**)**

References:

Ahmed, A.T. (1996). Food Legumes Production Situation. In: Salih, S.H., Ageeb, O.A., Saxena, M.C. and Solh, M.B., Eds., Production and Improvement of Cool-Season Food Legumes in the Sudan, Proceedings of the National Research Review Workshop, 27-30 August, 1995, Wad Medani; ICARDA/Agricultural Research Corporation, Aleppo, 7-14.

Agrawal, T.; Kumar, A.; Kumar, S.; Kumar, A.; Kumar, R.R. (2018). Correlation and path coefficient analysis for grain yield and yield components in chickpea (*Cicer arietinum L.*) under normal and late sown conditions of Bihar, India. Int J Curr Microbiol App Sci 7: 1633-1642.

Al-Jibouri, H.A; Miller, P.A.; Robinson, H. F. (1958). Genotypic and environmental variances and covariances in an upland cotton cross of inter specific origin. Agron. J. 50: 633-636.

Amare, T.; Asnake, F.; Muluken, B. (2020). Genetic variability and association analysis of Desi-type chickpea *(Cicer arietinum L.*) advanced lines under potential environment in North Gondar, Ethiopia, Cogent Food and Agriculture, 6:1, 1806668.

Amel, A. Mohamed.; Izzat, S.A. Tahir; Ashraf, M.A. Elhashimi (2015). Assessment of Genetic Variability and Yield Stability in Chickpea *(Cicer arietinum L.)* Cultivars in River Nile State, Sudan. Journal of Plant Breeding and Crop Sciences, 7(7): 219-224.

Banik, M.; Deore, G.N.; Mandal, A.K.; Shah, P. (2017). Selection of yield contributing traits in chickpea genotypes by correlation and path analysis studies. J Pharm Innov 6: 402-405.

Basu, P.S.; Ali, M.; Chaturvedi, S.K. (2009). Terminal heat stress adversely affects chickpea productivity in northern India- Strategies to improve thermo tolerance in the crop under climate change on Agriculture, 23-25 February, New Delhi, India, Pp. 189-193.

Bozoglu, H.; Ozcelik, H. (2005). A Study on determination of genotype x environmental interactions and stabilities of some genotypes in chickpea (*Cicer arietinum L.*). GAP Fourth Agricultural Congress. Uni. Har. Fac. Agr.,Sanliurfa,1: 834-839.

Ciftci, V.; Togay, N.; Togay, Y.; Dogan, Y. (2004). Determining Relationships among Yield and Some Yield Components Using Path Coefficient Analysis in Chickpea (*Cicer arietinum L.*). Asian Journal of Plant Sciences, 5: 632-635.

Dasgupta, T.; Islam, M.O.; Gayen, A. (1992). Genetic variability and analysis of yield components in chickpea (*Cicer arietinum L.).* Annals Agric. Res., 13:157-160.

Devasirvatham, V.; Gaur, P.; Mallikarjuna, N.; Raju, T.N.; Trethowan, R.M.; Tan, D.K.Y. (2013). Reproductive biology of chickpea response to heat stress in the field is associated with the performance in controlled environments. Field Crops Research 142: 9–19.

Dewey, D.R.; Lu, K.H. (1959). A Correlation and path coefficient analysis of component of crested wheat grass seed production. Agronomy Journal 51:515-518.

Erman, M.; Ciffci,V.; Ciffci, H.H. (1997). A research on relations among the characters and path coefficient analysis in chickpea (*Cicer arietinum L*.). J Agric. Sci.; 3:43-46.

Eser, D.; Gecit, H.H.; Emeklier, H.Y. (1991). Evaluation of germplasm in chickpea (Cicer arietinum L.) landraces in Turkey. International Chickpea News alphabet No. 22-23 [PI. Br. Abst. 63(2): 1677; 1993].

Faki, H.H.; Sheick Mohamed, A.I.; Ali, M.E.K. (1992). Adaptation of chickpea in Sudan. In proceedings of the International Workshop on Adaptation of Chickpea in the WANA Region, 9-12 November 1992. ICARDA, Aleppo, Syria.

Fatih, E. A. Hamza; Amel, A. Mohamed (2018). Agronomic Performance, Genetic Variability, heritability and Interrelationship for Yield and Some Quantitative Traits of Some Chickpea (*Cicer arietinum L*.) Genotypes Grown in the Northern Sudan. Sudanese journal of Agricultural Sciences, 4 (1): 36 – 49.

Gaur, P.M; Kumar, J.; Gowda, C.L.L.; Pande, S.; Siddique, K.H.M.; Khan, T.N.; Warkentin, T.D.; Chaturvedi, S.K.; Than, A.M.; Ketema, D. (2008). Breeding chickpea for early phenology: perspectives, progress and prospects. In: Kharkwal MC (ed) Food Legumes for Nutritional Security and Sustainable Agriculture, Vol. 2, New Delhi, India: Indian Society of genetics and Plant Breeding, pp. 39-48.

GenStat for Windows (2009).12th Edition.VSN International Ltd., Hemel Hempstead, UK.

Jahhar, A.S.; Mane, B.N. (1991). Correlation and path-coefficient analysis in gram (*Cicer arietinum* L.). J. Mahars. Agri. Uni. 16: 204- 206.

Jeena, A.S.; Arora, P.P.; Ojha, O.P. (2005). Variability and correlation studies for yield and its components in chickpea. Legume Research 28:146-148.

Jha, U.C.; Basu, P.S.; Singh, D.K. (2015). Genetic variation and diversity analysis of chickpea genotypes based on quantitative traits under high temperature stress. International Journal of Bio-resource Stress Management 6: 700–706.

Jivani, J. V.; Mehta, D. R.; Vaddoria, M. A.; Raval, L. (2013). Correlation and path coefficient analysis in chickpea (*Cicer arietinum* L.). Electronic Journal of Plant Breeding, 4(2): 1167-1170.

Khan, I.A.; Bashir, M.; Malik, B.A. (1989). Character association and their implication in chickpea breeding. Pak. J. Agri. Sci., 26(2): 214-220.

Krishnamurthy, L.; Gaur, P.M.; Basu, P.S.; Chaturvedi, S.K.; Tripathi, S.; Vadez, V.; Rathore, A. (2011). Large genetic variation for heat tolerance in the reference collection of chickpea (*Cicer arietinum* L.) germplasm. Plant Genetics Research, 9(1): 59–69.

Kuldeep, R.K.; Pandey, S.; Babbar, A.; Mishra, D.K. (2014). Genetic variability, character association and path coefficient analysis in chickpea grown under heat stress condition. Electronic Journal of Plant Breeding 5(4):812-819.

Muhammd, S.; Hammad, M. N. T.; Rehmat, K.; Muhammad, J. A. K. S. (2002). Interrelationships and path analysis of yield attributes in chickpea (*Cicer arietinum* L.), Int. J. Agri. Biol., 4 (3): 404-406.

Ozveren Yucel, D.; Anlarsal, A. E.; Yucel, C. (2006). Genetic Variability, Correlation and Path Analysis of Yield and Yield Components in Chickpea (*Cicer arietinum* L.). Turk. J. Agric. For., 30: 183-188.

Shafique, M.S.; Muhammad, A.; Zafar, M.; Muhammad, A.; Awais, S. (2016). Genetic variability and interrelationship of various agronomic traits using correlation and path analysis in chickpea (*Cicer arietinum* L.). Acad J Agric Res 4: 82-85.

Shara, J. Hama. (2019). Correlation and Path Coefficient Analysis for Seed Yield and Yield Components in Chickpea under Rainfed Condition. Journal of Kerbala for Agricultural Sciences Vol.(6), No.(1): 26-35.

Sheikh Mohamed, A. I. (1991). Current status and future prospects of chickpea production in Sudan. International Chickpea Newsletter 24: 10-11.

Singh, K.B.; Bejiga, G.; Malhotra, R.S. (1990). Associations of some characters with seed yield in chickpea collections. Euphytica 49: 83-88.

Singh, N. P.; Ram, K.; Kumar, R. (2001). An assay of effects of different traits on chickpea grain yield. Annals. Agri. Res., 22(4): 564-569.

Singh, V.; Vimal, S.C.; Shrivastav, S.P.; Maurya, V.; Singh, N. (2017). Character association and path analysis of yield contributing traits and quality parameter in chickpea (*Cicer arietinum* L.). Journal of Pharmacognosy and Phytochemistry. 6 (5): 1488-1492.

Summerfield, R.J.; Virmani, S.M.; Roberts, E.H.; Ellis, R.H. (1990). Adaption of chickpea to agro climatic constraints. In: Van Rheenen, H.A., Saxena, M.C.(Eds.), Chickpea in the

Nineties, Proceeding of the second International workshop on chickpea Improvement, 4-8th December 1989. ICRISAT Publishing, India pp. 50-61.

Tadesse, M.; Fikre, A.; Eshete, M.; Girman, N.; Korbun, L.; Mohamed, R.; Bekele, D.; Funga, A. ; Ojiewo, C.O. (2016). Correlation and path coefficient analysis for various quantitative traits in desi chickpea genotypes under rainfed conditions in Ethiopia. J. of Agri Sci, 8(12):112.

Tejashwini, A.; Anand, K.; Sanjay, K.; Anil, K.; Ravi, R.K.; Sanjeev, K.; Singh, P.K. (2018). Correlation and path coefficient analysis for grain yield and yield components in chickpea (*Cicer arietinum* L.) under normal and late sown Conditions of Bihar, India. Int. J. of Current Microbiology and Applied Sciences. 7(2): 1633-1642.

Tesfamichael, S. M.; Githiri, S. M.; Nyende, A. B.; Rao, N. V. P. R. G. (2015). Variation for Agro-Morphological Traits among Kabuli Chickpea (*Cicer arietinum* L.) Genotypes. Journal of Agricultural Science; 7(7): 75-92.

Usman, S.; Qurban, A.; Naveed, M. T.; Saleem, M. (2012). Correlation analysis of seed yield and its components in chickpea (*Cicer arietinum* L.) genotypes. International Journal for Agro Veterinary and Medical Sciences, 6(4): 269-276.

Vaghela, M.D.; Poshiya, V.K.; Savaliya, J.J.; Davada, B.K.; Mungra, K.D. (2009). Studies on character association and path analysis for seed yield and its components in chickpea (*cicer arietinum* L.). Legume Res., 32(4): 245-249.

Vartika, S.; SC, V.; Shiv, P.S.; Virendra, M..; Nidhi, S. (2017). Character association and path analysis of yield contributing traits and quality parameter in chickpea (*Cicer arietinum L.)*. Journal of Pharmacognosy and Phytochemistry, 6(5): 1488-1492.

Wang, J.; Gan, Y.T.; Clarke, F.; McDonald, C.L. (2006). Response of chickpea yield to high temperature stress during reproductive development. Crop Science, 46: 2171-2178.

Yaqoob, M.; Ahmad, M.B.; Jan, H. (1990). Interrelationship between grain yield and other important characters in chickpea (*Cicer arietinum* L.). Sarhad J. Agric. 6: 159-164 [PI. Br. Absts. 61(10): 9673; 1991].