Selcuk Journal of Agriculture and Food Sciences

http://sjafs.selcuk.edu.tr/sjafs/index

Research Article

SJAFS

(2020) 34 (2), 154-161

e-ISSN: 2458-8377

DOI:10.15316/SJAFS.2020.210

Determination of Some Agronomic Traits and Their Correlation with Yield Components in Cowpea

Mustafa CERITOGLU[1,*], Murat ERMAN[1]

[1]Siirt University, Faculty of Agriculture, Department of Field Crops, Siirt, Turkey

ARTICLE INFO

Article history:
Received date: 29.05.2020
Accepted date: 26.06.2020

Edited by:
Ali KAHRAMAN; *Selçuk University, Turkey*

Reviewed by:
Mustafa ÖNDER; *SelçukUniversity, Turkey*
Ömer SÖZEN; *Kırşehir Ahi Evran University, Turkey*

Keywords:
Adaptation
Agronomic traits
Chlorophyll (SPAD-502)
Correlation
Heat stress
Vigna unguiculata

ABSTRACT

Cowpea is one of the vital grain legumes used for human and animal nutrition. Due to its rich protein content, cowpea supplies the protein requirement, especially in the African continent. Although cowpea is morphologically similar to common bean, it is a more tolerant species to heat and drought conditions. So, cowpea production has various advantages in semi-arid regions. The aim of this study was to determine some agronomic traits of used cowpea genotypes and evaluate their correlations with yield components. Plant height (PH), stem diameter (SD), leaf surface temperature (LST), total chlorophyll content (TCC), number of pods per plant (NP), number of seeds per plant (NS) and seed yield (SY) changed between 54.6-91.3 cm, 3.1-7.6 mm, 27.9-31.7 °C, 39-56.1%, 25.7-49.1, 307.5-684 and 646-2381 kg ha-, respectively. It is noteworthy that Karagöz produced the maximum SY compared to the other varieties. Besides, it was determined that SY has positive significant correlation with NS (r=0.98**), NP (r=0.96**), TCC (r=0.93**), SD (r=0.91**) and PH (r=0.86**).

1. Introduction

Food legumes play a significant and diverse role in the farming systems and the diets of poor people around the World (Stoilova, Pereira, Sousa and Carnide, 2005). Cowpea, *Vigna unguiculata*, is considered an essential grain legume adapted to sub-Saharan Africa (SSA) where it supplies to the nutrition, health, and income of rural and suburban inhabitants (Boukar et al., 2015).

Cowpea is the most produced grain legume on the World after common bean and chickpea. Additionally, due to its high nutritional value, cowpea is one of the most important legumes for indigenous Africa (Agbicodo, Fatokun, Muranaka, Visser et al., 2009). Cowpea seed contains 24.8% protein, 1.9% lipid, 6.3% fiber, 63.6% carbohydrate, ash, riboflavin, carotene and vitamin B1 (Stancheva et al., 2016). Generally, the production and consumption of cowpea is high in the world, Although, it is lower than other grain legumes in the Turkish market. The cowpea production area was nearly 12.5 million hectares in the World while it was produced in 13.5 thousand hectares in Turkey in 2018 (Food and Agriculture Organization of the United Nations [FAO], 2018; Türkiye İstatistik Kurumu [TUIK], 2018). The main reasons for the low production of cowpea in Turkey are low demand, lack of export opportunities and low grain yield per unit area and farmers turning to more profitable crops (Sert and Ceyhan, 2012).

Some problems occur in common bean cultivation in regions such as Southeastern Anatolia, where temperatures are high and precipitation is very low during the summer season (Sozen and Karadavut, 2017). High temperature has negative effects on plant growth and grain yield in common bean (Kazai, Noulas, Khah and Vlachostergios, 2019). However, cowpea can be easily grown in drought and subtropic regions. Incorporating to hot and dry conditions and minimal soil selectivity are the main reasons for the spread of cowpea cultivation worldwide (Kahraman, 2017; Simion, 2018). Cowpea generally favors hot climate and shows optimum growth in regions in which average temperatures are nearly 25 °C in summer (Boukar et al., 2015).

* Corresponding author email: *ceritoglu@siirt.edu.tr*

Cowpea is an important rotation crop. It forms a symbiosis with appropriate *Rhizobium* bacteria similar to other legumes. Despite the important role acted by biological Nitrogen fixation, little is known of the symbiosis between cowpea varieties and native or recommended *Rhizobium* spp. (Freitas, Silva and Sampaio, 2012). So, it provides more productive soil for the next seasons' plant (Sanchez-Navarro, Zornoza, Faz and Fernandez, 2019). The values are vary depending on the genotypic variation and ecological conditions (Makoi, Chimphango and Dakora, 2009). Moreover, due to their taproot system, cowpea allows aeration in the soil for a more productive and fertile rhizosphere in rotation systems. Simunji, Munyinda, Lungu and Mweetwa (2019) suggested that cowpea provides to improve yield on the second crop in rotation.

This is of concern due to the ecological constraints of the Southeast Anatolian region, the number of crop species adapted to local harsh climate is limited. Region's agriculture and farmers need novel products that have high adaptation potential and added-value. Cover crops in the region are exposed to strong heat stress and almost no rain in summer seasons (Table 2). Many crops can not cope with these ecological conditions. In all but few genera are negatively affected due to high temperature and drought conditions. Therefore, researching new plants that can be grown in the region is a need. The aim of this study was to understand different agronomic variations of various cowpea genotypes and their correlation with yield and yield components in semi-arid and high temperature conditions.

2. Materials and Methods

2.1. Study Site and Location

The study was conducted in Siirt University in 2019. The city where the study was laid out is located on 41° 57' east longitude and 37° 55' north latitude, Southeastern Anatolia Region of Turkey. The altitude of the city is 880 m.

2.2. Plant Materials and Experimental Design

In the study, 3 cultivars (Karagöz-86, Karnıkara and Akkız) supplied from a commercial company and 3 local populations (L_1, L_2 and L_3) collected from the Tokat, Samsun and Manisa regions were adopted. The cultivars used in the study are the most growth cowpea varieties in Turkey. The local populations are grown in different regions of Turkey and exhibit hopeful performance.

The study was laid out in a randomized complete block design with 4 replications. The plots were constituted as 4 rows and 9.6 m^2 (0.6 x 4) x 4. Row spacing and Intra-row distances were determined as 60 cm and 10 cm, respectively (Augustine, 2018).

2.3. Soil Analysis and Climatic Traits

According to Table 1, the soil of the trial area was composed of deep and medium-deep soil which is low in organic matter and phosphorus content, enough in potassium. Also, it was a little saline and limy. The texture of soil was clay loam, pH was alkaline near neutral (FMANR, 1990). Based on reference soil analysis results, 4 kg/da Diammonium phosphate was applied with sowing under the seed drill (Daramy, Sardoie-Addo and Dumbuya, 2016). Irrigation was done with a drip system. Weed control was realized with mechanical methods, not any chemical.

Table 1
Properties of soil in the study area

Deepth (cm)	0-20
Structure (Sand: Silt: Clay) (%)	39:6.3:54.6
pH	7.5
EC (dS/cm)	6.64
Lime (%)	9.3
Organic matter (%)	1.4
Phosphorus (kg/da)	1.91
Potassium (kg/da)	149

The region has characteristic temperature and humidity of the terrestrial climate. Temperature and humidity values of vegetation period were similar to the long years' average ranges. However, the rainfall was erratic and excessive compared with the long years average. Some climate data were given in Table 2.

Table 2
Some climate data belonging on area

Months	Rainfall (mm)		Average Temperature (°C)		Relative humidity (%)	
	2019	Long Years Average	2019	Long Years Average	2019	Long Years Average
March	182.0	92.3	8.3	10.1	63.5	59.2
April	175.6	91.7	11.9	15.3	66.8	53.8
May	64.4	69.5	21.9	20.0	41.8	49.6
June	1.2	10.8	29.1	27.0	26.5	28.7
July	2.0	2.6	31.8	31.7	19.9	20.4
August	1.4	1.9	32.0	31.6	19.3	19.6
Total	427	269				
Mean			22.5	22.6	39.6	38.6

2.4. Measurement of Traits

All traits investigated on 10 plants collected from per plot. Plant height (PH), number of pods per plant (NP), number of seeds per plant (NS) and seed yield (SY) were measured according to Erman and Çığ (2009). The Stem diameter (SD) was measured at 1 cm above the soil surface with an electronic digital caliper (Mitutoyo 500-182-30 digital caliper, Co. Ltd., Japan) (Verbree, Singh and Payne, 2015). Leaf surface temperature (LST) was measured with an infrared thermometer (SATO SK-8700, Co. Ltd., South Korea) with a 45^{o} angle and 10 cm distance to the leaf surface on a clear day between 12.00-14.00 during the flowering time (Yu, Wang, Xin and Zheng., 2016). Total chlorophyll content (TCC) of the leaf was measured with portable chlorophyll meter (SPAD-502, Minolta Camera Co. Ltd., Japan) on the upper fully expanded leaf at the beginning of flowering (Dong et al., 2019).

2.5. Statistical Analysis

The Shapiro-Wilk test was applied to evaluate the normality of data (Korkmaz et al., 2014). Data were calculated by analysis of variance in the R v.3.5.2 according to the randomized complete block design. The results were grouped according to the TUKEY test (Mangiafico, 2016). According to the results of multiple comparisons, significant differences ($P<0.01$) were determined between genotypes for all traits except leaf surface temperature. The correlation analysis of all the characters was calculated as per the procedure stated by Al-jubouri, Millar and Robinson (1958).

3. Results and Discussion

3.1.Agronomic traits

According to the results, cv. Karagöz had superior traits compared to others and it exhibited more tolerance in heat condition. PH, SD, LST, TCC changed between 54.6-91.3 cm, 3.1-7.6 mm, 27.9-31.7 °C, 39-56.1%, respectively (Table 4).

3.1.1. Plant height

The highest PH was determined in Karagöz (92.3 cm) while the shortest one (54.6 cm) was observed in L_2 (Table 3). However, the difference between L_2 and L_3 landraces was not significant. Different researchers reported that PH in cowpea changes between 27.9-108.5 cm (El-Naim, Jabereldar, Ahmed, Ismaeil et al., 2012; Bisikwa et al., 2014). Also, Massey, Singh, Nautiyal and Bhatt (2020) stated that PH is genotype-dependent and changes week by week during the growth period. Therefore, the adaptation potential of genotype to the environment has a vital role in PH.

3.1.2. Stem diameter

The thickest SD was in Karagöz while the thinnest one was in L_3 landrace (Table 4). According to these results, SD had a significant variation among genotypes. Verbree et al. (2015) stated that stem diameter, which is an important and easy phenotypic trait, may also be an indicator of response to drought stress in cowpea. Also, thicker stem in plants provides resistance them to lodging which is a vital reason for death in seedlings. Previous reports showed similarities with the result in this study. Ravelombola et al. (2018) stated that stem diameter value in cowpea affected by drought changed between 2.45-3.69 mm.

3.1.3. Leaf surface temperature

Differences among genotypes in terms of the LST was not significant (Table 3). Various researchers stated that changes in temperature affect plant growth and yield parameters (Olatunji et al., 2016; Kirigia, Winkelmann, Kasili and Mibus, 2018). Also, Hall (2004) stated that long term high temperature leads to unfavorable effects on seed yield in cowpea. Besides, Hesketh (1967) stated that the photosynthesis rate and amount of gas input and output through stomata decrease at high temperatures. However, more studies must be conducted with larger sets of genotypes to understand the tolerance and susceptibility levels in cowpea.

3.1.4. Total chlorophyll content

In terms of TCC, statistically significant ($P<0.01$) differences were determined among genotypes (Table 3). While the highest TCC was obtained from Karagöz, the lowest values obtained from L_3 landrace (Table 4). Chlorophyll as one indicator of heat-stricken plants is synthesized with ecological and genetic factors and its amount shows diversity for each species (Hendriyani and Setiari, 2009). So, the measurement of chlorophyll content is an indicator of photosynthesis intolerant plants. Higher chlorophyll content in Karagöz shows that its adaptability to heat conditions is superior compared with the other genotypes. Different studies supported the results (Karuwal, Suharsona, Tjahjoleksona and Hanif, 2017). Also, Barro et al. (2018) stated that TCC varied from 42.20 to 62.00% among the cowpea genotypes with a general mean of 51.38%.

Table 3
Some agronomic traits of genotypes

Genotypes	Plant height (cm)	Stem diameter (mm)	Leaf surface temperature (°C)	Total Chlorophyll Content (%)
L1	62.7cd	4.3c	31.7	49.1bc
L2	54.6d	3.4d	29.1	39.0d
L3	57.1d	3.1d	31.6	36.3d
Karnıkara	68.8c	5.1c	27.9	46.4c
Akkız	78.2b	6.1b	30.6	51.9ab
Karagöz-86	91.3a	7.6a	30.8	56.1a
Mean	68.8	4.9	30.3	46.5
TUKEY	28.8**	2.9**	17.0	14.6**

(**: $P<0.01$)

3.2. Yield components

The analysis of variances for yield parameters was given in Table 4. The Results pointed out significant differences among the genotypes on NP, NS and SY.

According to the results, NP, NS and SY changed between 25.7-41, 307.5-684 and 646-2381 kg ha^{-}, respectively (Table 5). The differences among genotypes are thought to be caused by adaptability to heat stress.

Table 4
Analysis of variance on three selected yield parameters

Source of variation		Number of pods per plant		Number of seed per plant		Seed Yield (kg/ha)	
	DF	MS	F prob.	MS	F prob.	MS	F prob.
Genotypes	5	237.5	**	45.8	**	13178868	**

3.2.1. Number of pod

The results showed that genotypes have different pod yield capacity (Table 5). Karagöz had the highest NP (49) while the L_3 had the least (25.7). Oladejo, Akinwale and Obisesan (2011) reported NP between 34.78-67.25. The NP is one of the most substantial yield components and it is affected by environmental stress factors such as heat or drought that causes the death of pollen grains and denaturation of physiological tissues (Al-Assafi and Abed, 2014; Abed, 2017). It is thought to be caused by genetic differences among genotypes concerning growth potential, nutrient uptake efficiency and yield capacity. Moreover, the adaptability of genotypes also affects yield parameters.

3.2.2. Number of seed

The NS changed based on genotypes. The highest NS was found in Karagöz and the lowest one was in L_3 (Table 5). Oladejo et al. (2011) pointed out that seed yield changes depending on traits of cultivars and environmental factors. As it is seen in growth and yield parameters, some cowpea genotypes, especially Karagöz and Akkız, showed hopeful performance for the region. It can show the reason for this cowpea grows best in the regions where average temperatures vary between 15-25 °C and night temperatures should not be less than 15 °C in growth period (Boukar et al., 2015). So, it is thought that the region is suitable for cowpea cultivation and choosing genotype has a vital role in high yield. Also, it is known that ecological conditions and cultivars have a significant effect on yield parameters. Some researchers stated that yield components change depending on genotypes and their adaptability to the local conditions (Basaran, Ayan, Acar, Mut et al., 2011; Agele, Oyewusi, Fayeun and Famuwagun, 2017). Aliyu, Lawal, Wahab and Ibrahim (2019) stated that NS varied from 22 to 360.

3.2.3. Seed yield

A highly significant variation was observed among the test genotypes under investigations (Table 4). The highest seed yield was obtained from Karagöz (2381 kg ha^{-}) while the lowest one (646 kg ha^{-}) was determined in L3 (Table 5). It is noteworthy that Karagöz variety produced the maximum SY compared to the other varieties. This is so because according to Ogbonnaya et al. (2003), cowpea is recognized to have extreme stomatal control leading to rapid closure of stomata under stress conditions. Also, Reza (2011) stated that seed yield is a polygenic trait. Horn, Shimelis, Sarsu, Mwadzingeni et al. (2018) revealed that genetic diversity affects grain yield both alone and depending on environmental factors. So, it can be understood that while genetic traits of material effect on adaptability to regions, growth parameters, physiological properties, yield components, and it also affect the seed yield, directly or indirectly. Kyei-Boahen, Savala, Chikoye and Abaidoo (2017) denoted that grain yield changed between 1097-1674 kg/ha in cowpea depending on various chemical and biological fertilization applications.

Table 5
Yield and some yield components of genotypes

Genotypes	Number of pods per plant	Number of seed per plant	Seed Yield (kg/ha)
L1	38.6bc	478.9bc	1599c
L2	34.1c	422.8c	1334d
L3	25.7d	307.5d	646e
Karnıkara	36.6bc	478.7bc	1514c
Akkız	41.0b	559.7b	1850b
Karagöz-86	49.0a	684.0a	2381a
Mean	37.5	488.6	1554
TUKEY	14.4**	268.1**	437.3**

3.3. Correlations among agronomic traits in cowpea

The summary of the correlation coefficients between SY and other traits average is presented in Table 6. The results presented positive and significant correlation was observed among the major of the agronomic traits evaluated. It shows that there were significant positive correlations between SY and NS (r=0.98**), NP (r=0.96**), TCC (r=0.93**), SD (r=0.91**) and PH (r=0.86).

It is seed as Table 6, the relationship between NS and SY showed the highest positive correlation (r=0.98**). Besides, NP has the highest correlation after NS. The results are the indicator that NP and NS have a vital role in total grain yield. Various researchers found a high correlation among NP, NS and SY (Alidu, Atokple and Akromah, 2013; Shanko, Andargic and Zelleke, 2014; Patel, Kumar and Meena, 2018).

Table 6
The results of correlation analysis between seed yield and other parameters

	PH	SD	LST	TCC	NP	NS
SD	0.95**					
LST	0.04	-0.05				
CC	0.89**	0.90**	0.03			
NP	0.86**	0.88**	-0.06	0.92**		
NS	0.90**	0.93**	-0.07	0.93**	0.96**	
SY	0.86**	0.91**	-0.08	0.93**	0.96**	0.98**

(PH: Plant height, SD: Stem diameter, LST: Leaf surface temperature, TCC: Total chlorophyll content, NP: Number of pods per plant, NS: Number of seeds per plant, **: p<0.01)

Otherwise, TCC had a significant correlation with NP (r=0.92**), NS (r=0.93**) and SY (r=0.93**). The well-known role of photosynthesis products on plant growth also affects metabolic activities (Duca, 2015). Several researchers stated that there is a direct positive correlation between TCC and yield parameters (Esaghira et al., 2016; Musa, Bashir and Tadda, 2017; Sozen and Karadavaut, 2018). Besides, SD had a significant correlation with NP (r=0.88**), NS (r=0.93**) and SY (r=0.91**). It can be commented that the plants which have thicker stem diameter are more tolerant of heat conditions exhibited superior performance in terms of yield parameters (El-Naim et al., 2012). Also, a significant correlation was determined between PH and NP (r=0.86**), NS (r=0.9**), SY (r=0.86**). Walle, Mekbib, Amsalu and Gedil (2018) demonstrated that genetic correlations are more effective than phenotypic correlations in cowpea and it was revealed that PH has a favorable relationship with yield components.

4. Conclusion

From the results obtained in the study, Karagöz exhibited superior properties compared to others in terms of morphological growth, total chlorophyll content of leaf, seed yield and some yield components. The results of the study indicated that genetic traits have a significant effect on yield parameters and some other traits. The cowpea genotypes have different adaptation capacity due to their genetic traits and show various responses to conditions under investigation. Additionally, it was concluded that cowpea cultivation has some advantages in semi-arid regions. The number of seeds per plant and the number of pods per plant have the highest correlation values with seed yield. It must be laid out further studies on the genotypic variation and local adaptation potentials of cowpea cultivars.

5. Acknowledgments

This research was conducted in the study areas of Siirt University. The authors thank Dr. Ayman El SABAGH and Dr. Harun BEKTAS for their contributions.

Statement of Conflict of Interest

The authors have declared no conflict of interest.

Author's Contributions

The contribution of the authors is equal.

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